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Butler University Botanical Studies

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CORRELATION OF ELONGATION IN WHITE AND RED PINE WITH RAINFALL[1]

By JERRY ANNE MOTLEY

Research in height growth has been carried on in the east by Kienholz (5), (6), Cook (2) and Baldwin (1); in the middle west by Rees (8) and Friesner (3), (4); and in Montana by Kirkwood (7).

Kienholz showed from his observations on red oak (*Quercus rubra*), white ash (*Fraxinus americana*), beech (*Fagus grandifolia*), sugar maple (*Acer saccharum*), red maple (*Acer rubrum*), gray birch (*Betula populifolia*), white or paper birch (*Betula alba papyrifera*), yellow birch (*Betula lutea*), tulip poplar (*Liriodendron tulipifera*), large-toothed aspen (*Populus grandidentota*), trembling or quaking aspen (*Populus tremuloides*), red pine (*Pinus resinosa*), and European larch (*Larix decidua*) that these species fall into two groups according to seasonal length growth. To the first group belong the red oak, white ash, beech, sugar maple, red maple and red pine. Red oak and white ash started growth late in April and reached a peak of the most rapid growth in the latter part of May, then fell off suddenly and ceased in the latter part of June. Ninety percent of the growth was made in 30 days, for red oak from May 5 to June 5 and white ash from May 10 to June 10. Beech started and ceased growth earlier than red oak. Sugar maple and red maple ceased growth later than white ash. Red pine and red maple proved to be similar, with red pine beginning its growth late in June and ceasing in the middle of July. The red pine growing season was 70 days, 90% of growth completed in 60 days from May 10 to June 30.

To the second group belong the gray birch, white or paper birch, yellow birch, tulip poplar, large toothed aspen quaking aspen and European larch. Gray birch and paper birch started growth late in April, reached a peak in mid-June and fell off gradually in mid-August. The period of elongation here was 110 days, 90% of it being completed in about 60 days (May 20-July 20). Yellow birch followed a similar pattern "but started, reached its peak, and ceased a little later than gray birch." The few measurements taken from tulip poplar, large-toothed aspen and quaking aspen showed that growth curves were much alike. European larch was similar to the birches with the growth "coming later in the season." Lack of rainfall affected only the first year sprouts.

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[1] A portion of a thesis submitted in partial fulfillment of the requirements for the Master of Science degree in the Division of Graduate Instruction, Butler University.

Cook (2) found in his studies of red pine (*Pinus resinosa*), American larch (*Larix laricina*), European larch (*Larix decidua*), red spruce (*Picea rubra*), white spruce (*Picea glauca*), Norway spruce (*Picea abies*) and western hemlock (*Tsuga canadensis*) that initiation of growth differed considerably. In red pine growth began May 4 and red spruce June 3 with the other species placing between these two dates. Pine and spruce had a growing period of 50-60 days, hemlock 85, and larch 100. Completion of growth took place in red pine before July 1 and in the larches during September. "Red pine is in a class by itself, with an early start, rapid growth, short season, and an abrupt ending." White pine grow about 7-10 days longer; white and Norway spruce start later, grow rapidly, and stop suddenly. "Red spruce has a curve similar to red pine, but is consistently a month later. Hemlock and the larches start late and have a very long growing season." Great deficiency in rainfall retarded growth. The growth curve was constant from year to year in several cases.

In Baldwin's (1) studies of balsam fir (*Abies balsamea*), white spruce (*Picea glauca*), red spruce (*Picea rubra*), black spruce (*P. mariana*), white pine (*Pinus strobus*), red pine (*Pinus resinosa*) and northern white cedar (*Thuja occidentalis*) the period of height growth was about 12 weeks, 90% of growth occurring during 6 weeks. "Growth was slow during the first month, rose rapidly to a maximum, and sank again rapidly, demonstrating clearly the grand period of growth."

Rees (8) working in Minnesota with red spruce (*Picea rubra*) found that primary growth began the latter part of May and was completed in mid-July. He reported a slight elongation in the terminal leader until the latter part of July. There was a cessation of secondary growth in the twigs and smaller branches about the middle of August.

Friesner (3), (4) studied elongation in white pine (*Pinus strobus*), red pine (*P. resinosa*), scotch pine (*P. sylvestris*) and Jack pine (*P. banksiana*). Elongation began by April 12 in all except white pine and in this species it began a week later. All individuals showed a grand period type of elongation. Both jack pine and the majority of scotch pine completed maximum elongation by the end of 4 weeks and red pine in 4-7 weeks. Heavy rains coming in June during the decelerating growth of these species had no affect on stopping this deceleration. All species reached a mid-summer zero point about the end of June and this was followed by a period of slight elongation: in some, due to bud development; and in a few, to further axial elongation. All of these studies have dealt with elongation during a particular growth season and have shown that trees in general may be grouped into two main groups with respect to the time and duration of their axial elongation: (1) short period trees in which 90% of their growth occurs in 50-70 days and (2) long period trees in which 75-105 days are required to complete 90% of the annual axial elongation. Both white and red pine belong to the short period group.

Kirkwood (7) found that annual height growth in *Pinus ponderosa* and *Pseudotsuga taxifolia* showed closest correlation with the rain which fell during the "storage" season of the preceding year.

METHODS

Measurements for a 9-year period of elongation were taken of the main stems and lower secondary branches of white pine, and red pine on a northwest-facing slope in Brown County, Indiana. One hundred main stems of white pine and 50 of red pine were measured. Four lower secondary branches were measured on each tree. Measurements were made with calipers and recorded in millimeters. From the tip of the bud to the top of the first false whorl of branches was measured as the past season's growth, then from the top of the first false whorl of branches back to the top of the second false whorl of branches was taken as the second preceding year's growth and so on until the entire axis was measured. These measurements were taken for elongation which occurred from 1946 as far back as the year 1938.

Curves were plotted for both the main stems and secondary stems. Composite curves, combining measurements of all stems of each species, were also made for both the main and secondary axes.

Rainfall data for the area in which these trees grew was obtained from the United States Weather Bureau, Indiana Section, Hickory Hill and Kelly Hill Stations. In addition to the monthly and annual rainfall periods, curves were plotted for the following partial years: the elongation and pre-elongation season: January-June, March-June, April-June, May-June and April-May; and the storage season: May-November, June-November, July-November, August-November, May-October, June-October, July-October, and August-October.

ANALYSIS OF RESULTS

White Pine

The composite data of main stems of 100 white pine (*Pinus strobus*) trees (table I and fig. 1) show a steady increase in rate of elongation from 1937 to 1940 followed by a sharp decline in 1941. This was followed by three more seasons (1942-1944) of high elongation rate with another sharp decline in 1945. The elongation for 1946 showed an average of 819 mm per tree which was more than double the average (385 mm) for the previous year. The 1941 slump in elongation rate was shared by 56 trees out of 68 which were then old enough to be considered, i. e., showed elongation measurements from 1937 on. Eleven of the remaining 12 trees showed slight increases in 1941 and one showed the same elongation in 1941 as in 1940. The 32 trees which were too young for consideration regarding the 1941 slump showed earliest elongation measurements for 1939. The 1945 slump in elongation was exhibited by 99 of the 100 trees measured, and the enormous increase in elongation (over 100%) in 1946 was exhibited by every tree measured.

The data for elongation of older secondary branches (table I and fig. 1) yield a similar, though not so striking picture: a gradual rise from 1937 to 1940, the 1941 slump, the renewed increasing rate in 1942 and 1943 with the 1945 slump, and the 1946 increase all being represented.

When this elongation behavior is compared with rainfall behavior (comparing figures 1 and 3) for what might be called the "storage season," i.e., May to November inclusive (figure 3) it will be noted that: (1) a rainfall slump during May-November in 1940 is followed by an elongation slump in 1941; (2) increased rainfall for the same period during 1941-1943 is followed by increased elongation in 1942-

1944; (3) a marked slump in rainfall for May-November 1944 is followed by a very marked decrease in elongation in 1945; (4) an increase in rainfall of over 100% for May-November 1945 is followed by an increase in elongation of over 100% in 1946. If rainfall for May-October or June-October (instead of May-November) is considered, the relationship is not materially altered from that shown by May-November though the correlation with May-November or May-October is more striking than when the month of May is omitted from consideration.

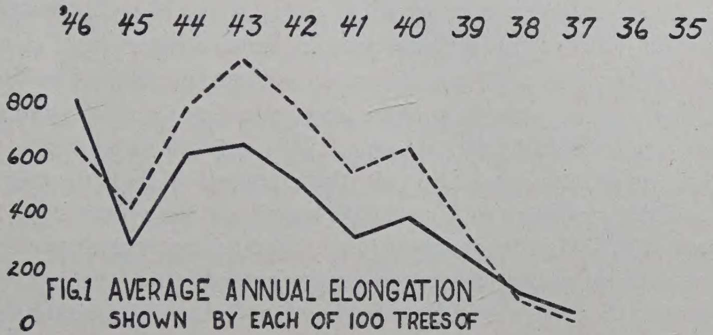

FIG.1 AVERAGE ANNUAL ELONGATION SHOWN BY EACH OF 100 TREES OF *PINUS STROBUS*

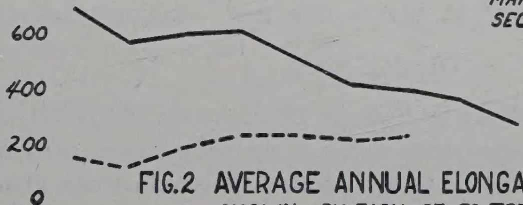

FIG.2 AVERAGE ANNUAL ELONGATION SHOWN BY EACH OF 50 TREES OF *PINUS RESINOSA*

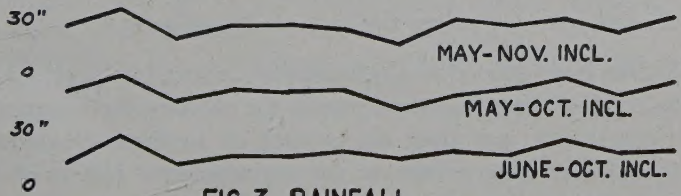

FIG. 3 RAINFALL

RED PINE

None of the red pines measured were old enough for consideration in comparing elongation and rainfall with respect to the 1940 rainfall slump (fig. 3) and the 1941 elongation slump shown by white pine (fig. 1). Composite data for red pine (table I and fig. 2) show the 1945 elongation slump shown by white pine. Of the 50 trees measured 33 show the 1945 slump in elongation, 13 show increases in 1945 and 4 show neither increased nor decreased elongation rate. The 1941 slump in elongation shown by white pine following the 1940 slump in rainfall is not shown by the red pine. This is taken to be due to the fact that the red pines had had only three seasons of growth prior to 1941 and these seasons were occupied largely by the young trees becoming established in their new surroundings following transplanting. Each successive season permitted better growth than the previous season until the trees could be thought of as being fully established. The secondary branches of red pine followed much the same pattern exhibited by the primary axes. The 1945 slump in elongation following the increased rainfall of 1945 is even more strikingly exhibited.

DISCUSSION

Since it has been shown by Friesner (3) that over 90% of elongation in white and red pine occurs during the period from mid-April to mid-June it is reasonable to assume that for much of the growth the plant must draw upon reserves of food stored during the period of lessened growth activity. Friesner also pointed out that rainfall during the period of maximum elongation had little effect by way of either increasing or decreasing the rate of elongation.

If the tree must depend to a considerable extent for its elongation rate upon the food reserves stored during the photosynthetic period of the previous season, and since the amount of food constructed and stored should bear some relation to the environmental factors of that period, it is obvious that one might reasonably expect some degree of correlation between rate of elongation and the environmental factors pertaining during the period when the reserves, upon which the life processes must draw, are being constructed. This expectation is met in the fact that increases or decreases in elongation rate occur in the growing season of the calendar year, following that in which marked increases or decreases in May-November rainfall occurred. These results on white and red pine thus follow closely the results obtained by Kirkwood (7) on ponderosa pine and Douglas fir.

SUMMARY

1. Measurements of annual elongation were taken of the main stems and secondary branches of 100 white pine, and 50 red pine trees. Curves of growth were plotted for both main and secondary stems and composite curves were made for each of these.

2. Rainfall data for the area in which the pines grew was collected and curves were plotted for various combinations of months.

3. Elongation in white pine showed closest correlation with rainfall of the "storage" season, May-November, of the preceding calendar year. This was true of both primary and secondary axes.

4. Red pine does not show as marked correlation between elongation and rainfall of the previous storage season as is shown by white pine.

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TABLE I

Summarized Elongation Data—Averages.

Year	White Pine		Red Pine	
	Primary	Secondary	Primary	Secondary
1946	819 mm	153 mm	706 mm	146 mm
1945	385	109	575	135
1944	644	112	609	195
1943	689	211	613	247
1942	527	200	520	249
1941	333	155	428	222
1940	471	232	415	232
1939	428	202	323	
1938	296	171	273	
1937	191	89		

A STUDY OF ORGANISMS IN SOIL SAMPLES FROM SOUTHERN INDIANA WHICH INHIBIT THE GROWTH OF ESCHERICHIA COLI AND STAPHYLOCOCCUS AUREUS[1]

By DORIS COLLIGAN

The purpose of this investigation was to determine the numbers and kinds of organisms—bacteria, actinomycetes, or fungi—found in certain soils which inhibit the growth of two test organisms. Soil samples collected from beneath different species of trees in wooded areas were used to ascertain what correlation there might be between the number and kind of inhibitors found and the kind of soil from which they were isolated.

This ecological aspect of the study of soil organisms which produce antibiotic substances has not been emphasized up to the present time by any of the workers studying antibiotics and the organisms which produce them, but it would seem to be of some value to have an idea where the largest number of most active inhibitors are found.

Certainly any study of soil organisms showing inhibition to other micro-organisms is valuable since notations like the following in a paper by Hoogerheide (5) are common in botanical literature:

> "Waksman and Woodruff isolated from the soil in 1940 a new chromogenic species of Actinomyces which showed strong antagonistic properties toward all bacteria belonging to both the Gram-positive and Gram-negative types. This new species was later described as *Actinomyces antibioticus.*"

Much work remains to be done in the search for new antibiotic substances to combat plant and animal diseases.

PROCEDURE

Soil samples were collected in October, 1947, from wooded areas in southern Indiana in regions of unglaciated clay soil: at Cornus Ridge, in Brown County, and at Stoney Lonesome, in Bartholomew County. The samples of soil were collected under seven different kinds of trees. From the Cornus Ridge area the trees used were *Pinus strobus, Liriodendron tulipifera,* and *Quercus montana;* while at Stoney Lonesome soil was collected under *Acer saccharum, Carya ovata, Liriodendron tulipifera, Juglans nigra,* and *Quercus alba.*

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[1] A portion of a thesis submitted in partial fulfillment of the requirements for the graduation honor magna cum laude, Department of Botany, Butler University.

Two samples were taken from beneath each tree, one from the surface soil and one at a depth of two or three inches, so that a comparison might be obtained between the number of inhibitors at the two depths. In collecting the surface soil, care was taken to avoid getting only the humus material on top of the ground. When the subsurface sample was taken, the surface earth was turned back first and then the soil taken from two or three inches down. An alcohol lamp was used to flame the trowel used in taking samples so that organisms would not be carried from one area to another, and the soil was put into paper bags, numbered according to location and lettered "A" for surface soil or "B" for subsurface soil.

Two methods of proceeding to find organisms in the soil which would inhibit the growth of the test organisms, *Escherichia coli* and *Staphylococcus aureus,* were tried. Up to a certain point both methods were parallel: one gram of soil was allowed to stand overnight in 10 cc. of sterile distilled water. One cc. of this was again diluted in 10 cc. of sterile distilled water, making a dilution of 1-100. One cc. of the 1-100 dilution of soil was plated with sterile pipettes into each of 14 sterile petri dishes. Seven of these petri dishes contained agar at at suitable pH for the growth of bacteria and actinomycetes and the other seven were poured with agar suitable for the growth of fungi. Following are the formulae for the media used:

Medium I (for bacteria and actinomycetes):

Dextrose	10 grams
Beef Extract	5 grams
$NaCl$	5 grams
Peptone	5 grams
Agar (2%)	20 grams
Water	1 liter

Medium II (for fungi, pH lowered to about 4.5 by the addition of corn steep liquor):

Dextrose	30 grams
$NaNo_3$	3 grams
K_2HPO_4	0.5 grams

$MgSO_4$	0.5	grams
$ZnSO_4$	0.01	grams
Agar (2%)	20	grams
Water	1	liter
Corn Steep Liquor	2.6	cc.

These plates were incubated at 37° C. for from two to five days, the growth of the fungi being somewhat slower than that of the bacteria and actinomycetes.

At this point the two methods diverge. The first method used was that of inoculating tubes of agar with *E. coli* and *S. aureus* and pouring this on top of the soil sample cultures after there was sufficient growth on the plates. Zones of inhibition to *E. coli* and *S. aureus* would then be visible around the colonies from the soil which produced a substance inhibitory to the test organisms. This method proved unsatisfactory, however, because it was not always easy to ascertain whether a colony was inhibiting the test organisms. Also it was extremely difficult to obtain a pure culture of the soil colony doing the inhibiting due to the fact that it was covered with the layer of agar containing *E. coli* or *S. aureus.*

These difficulties led to the use of the second technique, the isolation from each soil plate of all colonies differing in appearance. The first method was used on six samples, the second technique on the other ten. The number of plates poured for each soil sample was cut from 14 to 10 with this change in technique. Five plates were poured with each of the two types of agar.

Two hundred twenty-one colonies were isolated from the 16 soil samples used. Each organism was numbered as it was isolated and notation was made of which numbers came from each soil sample. When colonies were isolated they were cultured on the same type of agar on which they originally appeared except in two or three cases where growth seemed to be very poor and a switch to the other type of agar brought about a better growth response.

To test for the antibiotic production from each type of colony isolated, one streak of the organism being tested was made across an agar plate and allowed to grow for from two to four days at 37° C. This growth period was allowed so that the organism might have sufficient time to produce any substance which would inhibit the growth of *E. coli* or *S. aureus*. When this incubation time had elapsed the plates were inoculated with the two test organisms, one line of inoculation being made at a right angle to the line of growth of the organism being tested. The inoculation was done with the sterile loop from the line of growth to the edge of the petri dish.

Other workers (5) have allowed time for the "antagonist" to develop into a colony and excrete sufficient antibiotic substances before the test organism develops by seeding the agar plate first with a slow-growing test organism, such as *Mycobacterium phlei*, and afterwards inoculating the plate with the organism being tested.

Readings of inhibition were made after 48 to 72 hours, the amount of inhibition being recorded in millimeters or, if the growth was not completely inhibited but only seemed to be retarded, the amount was recorded as slight inhibition. This second method used is similar to one described by Helner and Norton (4):

> "Our procedures were adapted from those described by Waksman, Bugie, and Schatz (1944) and in general resembled those described by Emerson et al. (1946). The actinomycetes were isolated from greenhouse soil (a rich and convenient source) by plating the soil in nutrient agar and selecting colonies of actinomycetes for isolation. The selection of colonies of actinomycetes was made entirely at random, no attempt being made to pick colonies differing from one another in appearance, nor to favor colonies which were inhibiting other soil organisms growing in the same plate. We assumed that different strains of the same species of *Actinomyces* differed in antibiotic potentialities and that colonies apparently inactive on the primary isolation plate might be active producers of antibiotics after prolonged incubation. . . . The preliminary screening of the isolates for antibiotic activity was made by growing them on plain nutrient agar for 4 to 8 days at room temperature, after which their action against *E. coli* and sometimes *Mycobacterium smegmatis*, was determined by streaking the bacteria on the same plate and observing zones of inhibition."

Those organisms found to produce an inhibitory substance were stained and examined with the microscope to determine which were bacteria and which actinomyces and also to determine the Gram stain reaction of the bacteria.

RESULTS

Twenty-seven organisms which inhibited the growth of *E. coli* and/or *S. aureus* were isolated from the 16 soil samples.

In four of the soils tested the number of inhibitors found below the surface of the soil was greater than the number found at the surface (table I). These four cases were the samples from under *Liriodendron tulipifera* (Cornus Ridge), *Quercus montana, Carya ovata,* and *Juglans nigra.* In the samples representing the soil under *Pinus strobus, Acer saccharum, Liriodendron tulipifera* (Stoney Lonesome), and *Quercus alba* the number of organisms inhibiting *E. coli* and/or *S. aureus* at the surface was either the same or greater than those found at a depth of two to three inches.

The greatest number of inhibitors, both at the surface and below the surface, was found in the soil samples from beneath *Quercus montana* and *Juglans nigra,* both contributing six organisms to the study. *Liriodendron tulipifera* (Cornus Ridge) was next with 5 organisms, *Liriodendron tulipifera* (Stoney Lonesome) and *Quercus alba,* 3 each; *Pinus strobus,* 2, and *Acer saccharum* and *Carya ovata,* 1 each (table I).

The largest zone of inhibition, 30 mm., was produced against *E. coli* by an actinomycete from the subsurface soil beneath *Juglans nigra* (table II). The surface soil from *Quercus alba* and *Acer saccharum* each gave a bacterium which produced a zone of inhibition of 22 mm., in the former case against *E. coli* and in the latter case against *S. aureus.* Eleven other organisms gave inhibition zones of 10 mm. or more against *E. coli* and/or *S. aureus.*

TABLE I

Number of inhibitors of *E. coli* and/or *S. aureus* found in soil samples from beneath eight trees.

	Number of Inhibitors in Surface Soil	Number of Inhibitors in Subsurface Soil	Total
Pinus strobus	1	1	2
Liriodendron tulipifera (Cornus Ridge)	2	3	5
Quercus montana	1	5	6
Acer saccharum	1	None	1
Carya ovata	None	1	1
Liriodendron tulipifera (Stoney Lonesome)	2	1	3
Juglans nigra	2	4	6
Quercus alba	2	1	3

TABLE II

Width of zone of inhibition produced by soil organisms.

		E. coli	*S. aureus*
Pinus strobus	Below Surface	3 mm. (actinomycete)	
Liriodendron tulipifera (Cornus Ridge)	Surface	13 mm. (actinomycete)	10 mm. (fungus) 2.5 mm. (fungus) 4 mm. (fungus)
	Below Surface	20 mm. (bacterium)[1] 11 mm. (bacterium)[1]	15 mm. (bacterium)[1] 14 mm. (bacterium)[1]
Quercus montana	Surface	slight[2] (fungus)	
	Below Surface	20 mm. (actinomycete) 2 mm. (fungus) 3 mm. (fungus) 7 mm. (fungus) 12 mm. (actinomycete)	12 mm. (actinomycete) 2 mm. (fungus)
Acer saccharum	Surface	15 mm. (bacterium)	22 mm. (bacterium)
Carya ovata	Below Surface		slight (actinomycete)
Liriodendron tulipifera (Stoney Lonesome)	Surface		slight (actinomycete) 5 mm. (actinomycete)
	Below Surface	13 mm. (bacterium)	slight (bacterium)

TABLE II—(Continued)

Width of zone of inhibition produced by soil organisms.

		E. coli	*S. aureus*
Juglans nigra	Surface	slight (actinomycete)	slight (bacterium)
		15 mm. (actinomycete)	13 mm. (actinomycete)
		slight[2] (actinomycete)	
	Below Surface	10 mm. (actinomycete)	
		30 mm. (actinomycete)	
Quercus alba	Surface	17 mm. (bacteria)	6 mm. (bacteria)
		22 mm. (bacterium)	12 mm. (bacterium)
	Below Surface	13 mm. (bacterium)	

E. coli proved to be more susceptible to the antibiotic substances produced by the inhibitors found in these soil samples than did *S. aureus,* as shown in table III. The actinomycetes not only made up the greatest number of inhibitors, but the total amount of inhibition produced by these organisms was greater than that of the fungi or bacteria (tables III and IV). Although the number of inhibitors which were fungi was almost the same as the number of bacterial inhibitors (7 and 6 respectively), the total amount of inhibition produced by the bacteria was more than three times that produced by the fungi. The Gram-positive bacteria proved to be more active than the Gram-negative, causing a larger total amount of inhibition, and the Gram-positive organisms were more active against *E. coli* than against *S. aureus.*

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[1] Possibly same organism.

[2] No complete inhibition; growth slightly retarded.

TABLE III

Total amount of inhibition by soil organisms in 16 soil samples representing 8 trees.

Classification of organism	Number of millimeters of inhibition		Total
	E. coli	S. aureus	
Fungi	12	28.5	40.5
Actinomycetes	111	30	141
Bacteria			
Gram +	50.5	26.5	77
Gram —	28	22	50
Total	201.5	107.0	308.5

TABLE IV

Total number of soil organisms showing inhibition in 16 soil samples representing 8 trees.

Classification of organism	Number of organisms showing inhibition			Total
	E. coli	*S. aureus*	*E. coli* and *S. aureus*	
Fungi	3	3	1	7
Actinomycetes	8	3	2	13
Bacteria				
Gram +	1	–	2	3
Gram —	–	1	2	3
Total	12	7	7	26

DISCUSSION

When more than one inhibitor was isolated from a given soil sample, care was taken to be sure all the organisms were different species, but some of the same species may have been isolated from different samples of soil. Since this study was a comparison between various soils, it was not necessary to know whether a given organism had been isolated previously from another sample.

Eleven of the 27 organisms isolated were taken from the fungus medium and 18 from the bacteria-actinomycetes medium. In some cases, however, colonies of fungi which produced inhibition to the test organisms were isolated from the bacteria-actinomycetes medium.

On the whole the greater number of inhibitors was found in the subsurface soil, 16 being found in this study in soil samples from below the surface as compared with 11 inhibiting organisms found in the surface soil samples. Table I shows that there is a much greater variation from tree to tree in the number of inhibitors found below the surface than in the number found at the surface.

Table II indicates in millimeters the size of the zone of inhibition produced by each inhibiting organism, which type of tree was represented by the soil from which the organism was isolated, whether the sample was taken at the surface or below the surface, and whether the organism was fungus, bacterium, or actinomycete. In one case in this table, the subsurface soil sample taken from beneath the *Liriodendron tulipifera* at Cornus Ridge, two inhibitors are listed separately which were later thought to be of the same species. These organisms, from two petri plate colonies differing in appearance, were isolated, but growth characteristics in the agar slants and morphological appearance when the organisms were stained led to the conclusion that the two organisms were the same. However, since they were Gram-positive short spore-formers it is possible that they are two separate species in spite of their morphological similarity. The amount of inhibition which the two organisms produced against *S. aureus* was almost the same, 14 and 15 millimeters, but there was a difference of 9 mm. (20 mm. for one and 11 mm. for the other) in the size of the zones of inhibition against *E. coli*. In computing the figures on amount of inhibition for table III these two organisms were considered as being the same species and an average of the two different amounts of inhibition was used. Where the amount of inhibition is recorded as slight in table II there was no completely clear zone where the test organisms had been entirely kept from growing, but there was a zone where growth had been retarded.

One colony which had inhibited the growth of both *E. coli* and *S. aureus* is omitted from these tables because when it was stained it was found to be a mixed culture of a Gram-positive coccus and a Gram-negative rod. Efforts to obtain a pure culture of both these organisms were defeated because the growth of the organisms was so exceptionally poor on both kinds of media and at 37° C. or at room temperature.

Since a different method of isolation was used on ten of the soil samples a comparison is possible between the number of organisms isolated and the number which proved to inhibit the growth of either or both of the test organisms (table V). Of the 184 organisms isolated from the ten soil samples, eleven showed inhibition to *E. coli* alone, six showed inhibition to *S. aureus* alone, and five were found which affected the growth of both organisms. A percentage of from 5.5 to 23.8 of the total number of organisms isolated from each soil sample showed inhibition to the test organisms. Coincidentally, these two extremes were found in the surface and subsurface soil respectively, from the same tree, *Quercus montana.* The soil samples from three of the five trees showed a greater percentage of inhibitors in the subsurface soil than in the surface soil. In one case, *Pinus strobus,* both percentages were the same, while in the soil from beneath *Liriodendron tulipifera* from Stoney Lonesome the percentage of inhibitors in the surface soil was twice that of the soil from two or three inches down.

TABLE V

Comparison of number of organisms isolated and number showing inhibition to *E. coli* only, *S. aureus* only, and both organisms in the 10 soil samples on which the second technique was used.

Soil Sample from		Total No. Organisms Isolated	Number Organisms Showing Inhibition to			Percentage of Organisms Showing Inhibition
			E. coli	*S. aureus*	*E. coli* and *S. aureus*	
L. tulipifera (Stoney Lonesome)	Surface	13		2		15
	Below Surface	14			1	7.1
Juglans nigra	Surface	22	1	1		9
	Below Surface	19	3		1	21
Pinus strobus	Surface	21	1			9.5
	Below Surface	21	1			9.5
L. tulipifera (Cornus Ridge)	Surface	19	1	1		10.5
	Below Surface	16		2	1	18.7
	Surface	18	1			5.5

TABLE V—(Continued)

Soil Sample from		Total No. Organisms Isolated	Number Organisms Showing Inhibition to			Percentage of Organisms Showing Inhibition
			E. coli	*S. aureus*	*E. coli* and *S. aureus*	
Quercus montana	Below Surface	21	3		2	23.8
Total		184	11	6	5	11.9

CONCLUSIONS

1. In the sixteen samples of soil studied for this investigation it was found that a greater number of organisms producing a substance inhibitory to *E. coli* and/or *S. aureus* were found in the samples taken at a depth of two to three inches than were found in the samples taken from the surface.

2. The soils from beneath *Quercus montana* and *Juglans nigra* were found to be the richest source of inhibitors.

3. There is a greater variation from tree to tree in the number of inhibiting organisms found in the subsurface soil than there is in the number of organisms found in the surface soils.

4. The actinomycetes isolated gave a larger total amount of inhibition than did the bacteria and fungi; the bacteria gave larger zones of inhibition than did the fungi.

5. The organism producing the largest single zone of inhibition was an actinomycete isolated from the subsurface soil beneath *Juglans nigra.*

6. *E. coli* was found to be more susceptible to antibiotic substances produced by the inhibitors than was *S. aureus.*

7. Of the 10 samples on which the second technique of isolating soil colonies was used, a percentage of from 5.5 to 23.8 of the total number of organisms isolated from each soil sample showed inhibition to the test organisms.

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ANTIBIOTIC PRODUCING ORGANISMS ISOLATED FROM THE WHITE RIVER CANAL, INDIANAPOLIS, INDIANA[1]

By FRED C. MINDACH

Although a number of antibiotic producing organisms have been isolated from soil, especially in recent years; little work has been reported on either microbial antagonisms or on the isolation of antibiotic producing organisms from water. A review of the literature indicates that no specific antibiotic substance has been reported for microorganisms isolated from either fresh or salt water.

Frankland (3) was the first to establish that *Eberthella typhosa* may survive in sterilized polluted water or in deep-well water for 20 to 51 days although it dies out in 9 to 13 days in unsterile surface water. Jordan, Russell, and Zeit (8) found that the typhoid organism was able to survive in sterilized tap water for 15 to 25 days, as against 4 to 7 days in fresh water; the bacteria died off even more rapidly in raw river or canal water, the survival time being reduced to 1 to 4 days. The degree of survival of typhoid organism in water was found to be in inverse ratio to the degree of contamination of the water, the saprophytic bacteria in the water apparently being responsible for the destruction of the pathogen. These conclusions were later confirmed.

Vacek (12) showed that among the factors responsible for the disappearance of *Eberthella typhosa* in water, the presence of certain water bacteria was found to be of special importance. Rochaix and Vieux (10) demonstrated that when an achromogenic strain of *Pseudomonas aeruginosa* was present in drinking water, it was not accompanied by any other bacteria. Media inoculated with this organism and *Escherichia coli* gave, after 13 days' incubation, only cultures of the former. That the two organisms could coexist, however, was shown by inoculation into sterilized water. Only the actual development of the antagonist led to the repression of the fecal organism. Studies made in Malta by Gilmour (5) and Horrocks (6) brought out the fact that *Brucella melitensis* survived in sterile tap water 42 days and in unsterile tap water only 7 days.

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[1] A portion of a thesis submitted in partial fulfillment of the requirements for the Master of Science degree in the Division of Graduate Instruction, Butler University.

Hutchinson, Weaver, and Scherago (7) while making a study of microorganisms antagonistic to *E. coli,* isolated organisms from 5 of 44 samples of well water, 1 of 12 samples of spring water, and 6 of 16 samples of surface water. The antagonists included 3 strains of Pseudomonas, 1 each of Sarcina, Micrococcus, Flavobacterium, and yeast, 2 actinomycetes, and 3 unidentified nonspore-forming gram-negative rods. No species identifications were cited in their work.

According to Waksman and Hotchkiss (14) and Zobell (15) sea water, also, appears to have a bactericidal effect upon organisms added to it. However, almost fifty years before, De Giaxa (4) observed that pathogens rapidly perish in raw sea water, although they may survive almost indefinitely in heat-treated sea water. Water from the Black Sea was found by Krassilnikov (9) to be germicidal for terrestrial bacteria until it is boiled. He confirmed the observations of Beard and Meadowcraft (1) and Zobell (15) that the bactericidal potency of sea water was decreased but not destroyed by passing it through Berkefeld, Chamberland, Coors, or similar filters. Rosenfeld and Zobell (11) concluded that, lacking the properties of bacteriophage, the bactericidal property of sea water is attributed primarily to its content of antibiotic substance produced by microorganisms. Credence is lent to this view by the observation that the bactericidal principle occurs in greatest concentration in samples of sea water recently collected from zones of maximum bacterial population. Of the 58 microorganisms isolated by Rosenfeld and Zobell from sea water, 9 showed antagonism toward fresh water or terrestrial organisms. Broken down into genera, the results are as follows: Bacillus, 4 of 9; Micrococcus, 3 of 6; Actinomyces, 1 of 2; Serratia, 1 of 1; Pseudomonas, 0 of 19; Vibrio, 0 of 11; Flavobacterium, 0 of 5; Achromobacter, 0 of 4; Sarcina, 0 of 1.

Waksman (13) emphasizes the fact that there are marked differences in the nature of the microbial population of waters and soils because of the physical and chemical differences in the composition of the two substrates. However, he continues by saying that some of the underlying principles apply to all substrates. There are, for example, marked differences in the nature and abundance of the populations of soil and water and those of milk, sewage, and foodstuffs. Whereas, microorganisms multiply in the latter substrates at a very rapid rate, those in the soil and in water basins are more nearly static, since the rate of their multiplication is much slower except under very special conditions, such as the addition of fresh, undecomposed plant and animal residues or a change in the environment or in the chemical nature of the substrate. Furthermore, the microbiological populations of soils, composts, and water basins are also influenced markedly by seasonal and temperature changes.

This work began as an attempt (1) to isolate antibiotic producing organisms from surface (river) water, and (2) if such isolations were possible, to determine the relationship between the maximum number of antibiotic producing organisms isolated and the bacterial population during the various seasons of the year.

Although circumstances necessitated altering the original problem, it is significant to note that preliminary investigation resulted in the isolation of microorganisms showing antagonism to other organisms. Two of these organisms, tentatively identified as *Achromobacter iophagum,* showed little or no antagonism toward test organisms and will be dealt with only briefly in this paper. However, two other microorganisms, tentatively identified as *Bacillus megatherium* and *Flavobacterium rigense,* showed appreciable antibiosis toward known organisms in the initial tests.

As mentioned earlier in this paper, Hutchinson, Weaver, and Scherago (7) reported the isolation of a strain of Flavobacterium showing antagonism to *E. coli.* However, no specific reference was made to species identification or the degree of antagonism produced. Rosenfeld and Zobell (11) isolated four species of Bacillus which showed antagonism to other organisms but, being salt water species, they are not directly comparable to *Bacillus megatherium.* Since none of their isolated strains of Flavobacterium showed antagonism to other organisms, no species identifications were mentioned in their report. To this writer's knowledge, no strain of *Bacillus megatherium* or *Flavobacterium rigense,* showing antagonism to other microorganisms, have been isolated before from fresh or salt water.

Due to the fact that preliminary procedures proved too time-consuming, it was decided to limit the present study to a more thorough investigation of the antagonistic properties of the isolated strains of *Bacillus megatherium* and *Flavobacterium rigense*. An attempt was made to determine (1) the production of antibiotic substances by the two organisms, and (2) the culture and incubation conditions under which maximum inhibitions were produced.

PROCEDURE

The water samples used for this work were collected from the White River Canal near the foot bridge on the Butler University campus. The canal water has its source from White River at the Broad Ripple headgates in the northeast section of Indianapolis. The original plan called for the collection of samples once a week for a period of one year.

On October 27, November 4, and November 8, 1947 water samples were collected in sterile, 180-ml aluminum-capped bottles. Special attention was given to sampling technique in order to make reasonably sure that any organisms isolated from laboratory cultures would be from the water and not from the air or other sources. Agar dilution plates were made from the water samples immediately upon arrival at the laboratory. The platings were completed within an hour after the samples were collected.

One series of agar dilution plates was made to determine bacterial counts. Dilutions ranging from 1 ml up to and including 1:10,000 were made, plated in nutrient agar, and incubated at 37.5° C. for 24 hours.

Two other series were made with dilutions ranging from 1 ml up to and including 1:10,000,000. These dilutions were plated with nutrient agar and a modified Czapek-Dox medium which will be referred to as C-D 1 medium in this paper. The pH of the former (organic) medium was reduced to 4.5, while no pH adjustment was made on the latter (synthetic-organic) medium. The pH of this medium was approximately 7.0. By using these media it was hoped that growth of fungi and true Actinomyces would be enhanced, while other organisms might be inhibited.

Formulae for these media are as follows.

NUTRIENT AGAR

Bacto-Beef Extract	3	gm
Bacto-Peptone	5	gm
Bacto-Agar	15	gm
Distilled Water	1	liter

C-D 1 AGAR

Bacto-Dextrose	20	gm
Bacto-Peptone	5	gm
KH_2PO_4	0.5	gm
$MgSO_4 \cdot 7\ H_2O$	0.25	gm
$FE\ SO_4 \cdot 7\ H_2O$	0.01	gm
Bacto-Agar	15	gm
Distilled Water	1	liter

The bacterial counts for the three agar dilution series were as follows: October 27, 4,600 colonies per ml; November 4, 4,200 colonies per ml; and November 8, 2,600 colonies per ml. Counts for the canal water* showed a maximum bacterial count of 650,000 colonies, a minimum of 200 colonies, and an average of 7,000 colonies per ml. Temperatures of the samples of water collected were 64° F., 56° F., and 46° F., respectively. The average yearly temperature was 55° F.

The agar dilution plates with nutrient agar (pH 4.5) and the C-D 1 agar were incubated at room temperature (approximately 25° C.) until good growth occurred on the plates, usually 24-96 hours. Only well isolated colonies were sub-cultured to agar plates containing the same medium as the plates from which the colonies were isolated. Once again a well isolated colony was selected and transferred to test tube agar slants of nutrient agar (pH 6.8) and also to slants of C-D 2 (synthetic) agar medium, another modification of the Czapek-Dox medium.

C-D 2 Agar

Bacto-Dextrose	40	gm
$NaNO_3$	2	gm
KH_2PO_4	1	gm

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* Taken from the Annual Laboratory Report of the Indianapolis Water Company.

$MgSO_4 \cdot 7H_2O$	0.5 gm
Bacto-Agar	15 gm
Distilled Water	1 liter

The purpose of sub-culturing these organisms on nutrient agar (pH 6.8) and on C-D 2 agar was to prove their ability to grow on these media before subsequent culture work was attempted.

From the three series of agar plate dilutions, sixty-seven organisms were isolated. Macroscopically, all but four appeared to be bacteria; the others appeared to be fungi. Due to an unavoidable lapse of time, twenty-two of these cultures were lost.

A single streak of each of the forty-five cultures remaining was made on pour-plates of nutrient agar (pH 6.8) and also on C-D 2 agar. The agar plates were incubated at room temperature until good growth of the unknown organisms appeared. Then approximately one inch streaks of *Micrococcus catarrhalis, E. coli, Staphylococcus aureus,* and *Penicillium chrysogenum* were made at right angles to and just in contact with the growth of the unknown organisms. The plates were incubated again at room temperature for 96 hours and observed at 24 hour intervals for evidence of inhibition.

In preliminary tests four of the forty-five unknown organisms tested showed inhibition to one or more of the known test organisms. These included unknowns Nos. 10 and 19, isolated from the water collected on October 27, 1947, and unknowns Nos. 28 and 41, isolated from the water collected on November 4, 1947. Inhibition zones ranged from 0 to 25 mm.

Tryptose-phosphate broth and agar media (pH 7.3) and nutrient broth and agar media (pH 6.8) were selected as the culture media for further work.

TRYPTOSE-PHOSPHATE MEDIUM

Bacto-Tryptose	20 gm
Bacto-Dextrose	2 gm
Sodium Chloride	5 gm
Disodium Phosphate	2.5 gm
Distilled Water	1 liter

.15% Bacto-Agar (added for broth enrichment)
2.0% Bacto-Agar (added for solid medium)

NUTRIENT MEDIUM

Bacto-Beef Extract	3	gm
Bacto-Peptone	5	gm
Distilled Water	1	liter

.15% Bacto-Agar (added for broth enrichment)
2.0% Bacto-Agar (added for solid medium)

Eighty to ninety ml of the broth media were transferred to each of several 250-ml Erlenmeyer flasks. These flasks were cotton-stoppered and sterilized at 15 lb. steam pressure for 15 minutes. This volume of medium allowed a large surface for growth of the organism, and also allowed for greater concentration of any antibiotic substance that might be produced.

Two hundred and fifty ml of the 2.0% agar media were transferred into separate 500-ml Erlenmeyer flasks, which were also cotton-stoppered and sterilized at 15 lbs. steam pressure for 15 minutes.

When the agar dilution plates were made, the melted agar, cooled to approximately 50 to 55° C., was pipetted in amounts sufficient to satisfy any dilutions made. Later, volumes of solid media necessary for the various dilutions were placed in separate culture tubes before sterilizing as above. Although this procedure seemed less accurate, it was found, after several dilution series had been made, that it was impossible to make many dilutions by pipetting before the cooled agar began to solidify. This either caused lumpy plates or necessitated repetition of portions of some series.

In the first series, tryptose-phosphate broth and nutrient broth flasks were inoculated with the four unknown organisms and incubated at 37.5° C. These cultures were allowed to incubate until good growth was evident or until such time as it was thought necessary to occur. Subsequent series at different incubation temperatures were treated in the same manner.

The first tests were usually made after the cultures had incubated from 3-5 days. Agar dilution plates were made from the culture flasks using agar medium corresponding to the original broth culture medium. The dilutions were made as agar dilution units; i.e., 2 ml of culture broth plus 18 ml of agar represented a 1:100 dilution, etc. All dilution plates were prepared to contain a final volume of 20 ml of medium in order to insure sufficient growing medium and to avoid excessive shrinkage of medium during incubation.

After dilutions had been made, and the agar had hardened thoroughly, the bottoms of the petri plates were sectioned and numbered with a china-marking crayon. Then, the plates were placed upright, and loop inoculations of aqueous suspensions of known test organisms were made on the surface of the culture medium in corresponding numbered sections of all plates. Control plates were made for each series. Fresh aqueous suspensions of the test organisms were made for each dilution series if more than a week's time elapsed between series. However, experiments proved that two-week-old suspensions grew readily on control plates. These suspensions were placed in the refrigerator when not in use.

After inoculation, the agar dilution plates were placed in the incubator in an upright position to avoid the spreading of inoculations into adjacent areas. In this manner, multiple cross-sectioning of the plates allowed for as many as eight or more inoculations of test organisms on the same plate. After 24 hours' incubation at 37.5° C., the plates were removed from the incubator and observed. Growth or lack of growth of the test organisms in the various dilutions was recorded. Only complete inhibition of the test organisms was recorded as lack of growth, and no attempt was made to measure partial or retarded growth.

After agar dilution plates had been made, the culture broth flasks were incubated for an additional period of time, approximately one week, and then the dilution series were repeated. Several difficulties were encountered in the initial dilution series, and a number of trials were made before the final procedure was adopted.

The procedure finally adopted was that of centrifuging; culture broth was transferred to large, sterile culture tubes and centrifuged at 1800 rpm. for 15 minutes. The supernatant liquid was carefully transferred to other sterile culture tubes and centrifuged again at 1800 rpm. for 15 minutes. This supernatant liquid was used for agar dilution plates. This procedure did not eliminate all organisms from the culture broth in some cases, but their growth on agar dilution plates was significant only in low dilutions. Condensation was overcome by removing the glass tops after the agar had been poured and allowed to solidify, and replacing them with sterile clay tops which were porous enough to absorb the condensate due to incubation.

In the subsequent series of broth cultures and agar plate dilutions, special consideration was given to the variation of incubation temperatures. In this way, optimum growing temperatures for the unknown organisms were ascertained. Also, the optimum growing conditions for the production of antibiotic substances by the organisms were determined. When agar dilution plates were incubated at 20° C., they were allowed to incubate for 48 hours. The primary purpose of this additional 24 hour incubation period was to insure sufficient time for growth of the known test organisms. However, all test organisms, with the exception of *Saccharomyces pastorianus* in a number of dilution series, showed very satisfactory growth on control plates after 24 hours' incubation. Although broth cultures were grown at room temperature (approximately 25° C.) for some series, no agar dilution plates were incubated at this temperature.

The strains of the known test organisms, acquired from the Eli Lilly Company and Butler University laboratories were: *Micrococcus catarrhalis* (Lilly), *E. coli* (Lilly), *Staphylococcus aureus* (Lilly), *Monilia albicans* (Lilly), *Saccharomyces pastorianus* (Lilly), *Pseudomonas aeruginosa* (Butler) *Serratia marcescens* (Butler), *Sarcina lutea* (Butler).

IDENTIFICATION OF UNKNOWN ANTIBIOTIC-PRODUCING ORGANISMS

Bergey's Manual of Determinative Bacteriology (6th edition) was used for the identification. Any variations from Bergey's identification are cited, and discussion is given.

UNKNOWN NO. 10

Organism: *Bacillus megatherium.* Bergey, pp. 714-715

Shape	rods
Size	1.5 microns by 3.0 to 5.0 microns
Grouping	singly, pairs, short chains
Motility and Cilia	Motile, flagellation not observed (Bergey: peritrichous flagella)
Gram stain	Gram positive
Spores	paracentral to paraterminal, .8 to 1.0 micron by 1.0 to 1.5 microns, cylindrical, not swollen
Cell contents	stain unevenly (vacuolated
Gelatin stab	slow liquifaction, crateriform to infundibuliform
Agar plate	creamy white, moist, with pellucid dots
Nutrient broth	heavy uniform turbidity

Purple milk	peptonization
Potato	abundant, slimy, creamy white changing to brown
Indole	not produced (Bergey: not reported)
Ammonia	produced
Nitrates changed to nitrites	no change
Starch	hydrolyzed
Acid only in	lactose, glucose, raffinose, dulcitol, sucrose, mannitol, and galactose
No acid or gas in	salicin (Bergey: acid in salicin)
Acid and gas in	no sugars
Methyl Red	negative (Bergey: not reported)
Citrate medium	citrate used as source of carbon
Optimum temperature	25° C. to 37.5° C.
Habitat	water (Bergey: soil, water, and decomposing material)

The only significant variation from Bergey's Manual is the failure of this organism to produce acid in salicin. No difficulty was experienced in identifying this organism in the keys for genera and species.

UNKNOWN NO. 19

Organism: *Flavobacterium rigense.* Bergey, p. 430

Shape	rods, with rounded ends
Size	.6 micron by .8 to 1.0 micron (Bergey: .75 micron by 1.75 to 2.5 microns)
Grouping	singly
Motility and Cilia	motile, flagellation not observed (Bergey: peritrichous flagella)
Gram stain	Gram negative
Cell contents	Uniform
Gelatin stab	yellow surface and sediment, stratiform liquifaction (Bergey: infundibuliform)
Agar plate	colonies white to yellow to brown, smooth
Nutrient broth	turbid, with pellicle; settles with age
Purple milk	no change
Potato	yellow, turning brown; spreading
Indole	not produced
Ammonia	not produced
Nitrates changed to nitrites	changed
Starch	not hydrolyzed
Acid only in	glucose (Bergey: no sugars)
Acid and gas in	no sugars
Acetyl methyl carbinol	not produced (Bergey: not reported)
Hydrogen sulfide	not produced
Methyl Red	negative (Bergey: not reported)
Citrate medium	citrate not used as source of carbon (Bergey: not reported)
Optimum temperature	20° C. to 25° C. (Bergey: 30° C. to 37° C.)
Habitat	water (Bergey: soil)

This organism differs from the description of *Flavobacterium rigense* in Bergey in size, acid produced in glucose, and in optimum growing temperature. Growth of this organism was very poor at 37.5° C.

This organism also agrees to a large extent with *Flavobacterium diffusum,* Bergey, p. 429, except that it shows no green pigment production in gelatin, nutrient broth or on potato. This led to the writer's choice of *Flavobacterium rigense,* although it seems possible that this organism may be a variation of either of the species.

OBSERVATIONS AND DISCUSSION

Due to the fact that organisms Nos. 28 and 41, identified as *Achromobacter iophagum,* showed so little evidence of antagonism toward the test organisms, the results from their study are not included in the present paper. Tables I and II are summary tables showing the maximum dilution potency of *Bacillus megatherium* and *Flavobacterium rigense* to the known test organisms at the various incubation temperatures.

The known test organisms include four gram negative and two gram positive bacteria, and two fungi. They are shown in this order on the tables for better comparison.

1. Bacillus megatherium

All broth cultures of *Bacillus megatherium* showed good growth when incubated at 37.5° C., 25° C., and 20° C. Greatest inhibition from tryptose-phosphate and nutrient broth cultures when both cultures and dilution plates were incubated at 37.5° C. was shown toward *Micrococcus catarrhalis* and *Saccharomyces pastorianus,* while no inhibition was shown toward *Pseudomonas aeruginosa* and *Serratia marcescens.* The tryptose-phosphate broth cultures showed a consistently greater production of antibiotic substance than did the nutrient broth cultures. Greatest inhibition was shown toward a gram negative bacterium and a fungus, while two other gram negative bacteria were not inhibited at all. Tables I-VIII of the original manuscript cover the results of *B. megatherium* against test organisms. These are not included in the present paper but are available for inspection in the bound copy of the original thesis in the Butler University Library.

When tryptose-phosphate and nutrient broth cultures were both incubated at 25° C. and the agar dilution plates were incubated at 37.5° C., we find a variation in the maximum potency of the two broth cultures. The tryptose-phosphate broth culture showed most inhibition to *Sarcina lutea* and *Staphylococcus aureus,* while the nutrient broth culture showed most inhibition to *Micrococcus catarrhalis* and *Saccharomyces pastorianus.* The greatest inhibition was shown toward a gram positive bacterium, followed by a gram positive bacterium and a fungus, and finally a gram negative bacterium. On the other hand, *Serratia marcescens* and *Pseudomonas aeruginosa,* two other gram negative bacteria, were inhibited in low dilution at these incubation temperatures, whereas, they were not inhibited when both broth cultures and agar dilution plates were incubated at 37.5° C. There is, also, clear evidence that although the cultures incubated at 37.5° C. produced more potent antibiotic substance toward some of the test organisms, the antibiotic substance was produced just as rapidly in the cultures incubated at 25° C., and it retained its potency for a longer period of time.

There was a sharp decline in the potency of the antibiotic substance produced when the tryptose-phosphate broth culture was incubated at 25° C., while the agar dilution plates were incubated at 20° C. Again, *Sarcina lutea* was inhibited in highest dilution followed by *Saccharomyces pastorianus.* No inhibition was shown toward *E. coli, Serratia marcescens,* and *Monilia albicans.*

When both tryptose broth culture and agar dilution plates were incubated at 20° C. we find an increase in the antibiotic substance produced as compared to the results when broth cultures are incubated at 25° C. and agar dilution plates were incubated at 20° C. Increased potency is evident, especially, toward *E. coli, Pseudomonas aeruginosa,* and *Staphylococcus aureus.* However, *Sarcina lutea* and *Saccharomyces pastorianus* again show the least resistance to the antibiotic substance.

A study of a *B. megatherium* culture which had been subcultured a number of times on to fresh agar slants and which was about nine weeks old when broth cultures were inoculated yielded a striking result in that the potency of the strain was reduced to one half or less during this time interval. This bears out the writer's suspicion that the organism was losing its potency during preceding weeks when work was being done at other incubation temperatures.

In a test on the effect of filtration on a broth culture of *B. megatherium* a portion of the original tryptose-phosphate broth culture incubated at 37.5° C. was passed through an ultra-fine bacteriological filter under vacuum. The filtrate was plated in agar dilutions and incubated at 37.5° C. and there was no evidence of inhibition to any test organism. This is taken to indicate that the antibiotic substance produced had been retained on the filter. Difficulties encountered with this filter and the negative results obtained made it impractical to continue further with this procedure.

2. FLAVOBACTERIUM RIGENSE

Growth and inhibition data for known organisms tested against broth cultures of *Flavobacterium rigense* gave the following results. When both tryptose-phosphate and nutrient broth cultures and agar dilution plates were incubated at 37.5° C. lack of inhibition of any test organisms indicated that no antibiotic substance was produced in either culture. No growth was observed in either broth culture at any time during their incubation periods. When no growth occurred at the end of a five week incubation period, the cultures were discarded. Repeated inoculations of both broth media again showed no evidence of growth. Later, after several attempts, a slight growth of the Flavobacterium strain was attained on a nutrient agar slant incubated at 37.5° C. Tables IX-XV of the original thesis give the results of the tests with *F. rigense*.

On the other hand, tryptose-phosphate and nutrient broth cultures of this organism grew rapidly and vigorously at 25° C. Agar dilution plates made from these cultures showed inhibition to all test organisms when incubated at 37.5° C. The tryptose-phosphate broth culture showed a decidedly greater production of antibiotic substance than did the nutrient broth culture. *Sarcina lutea* was inhibited in highest dilution, while *E. coli* showed the greatest resistance.

When both tryptose-phosphate and nutrient broth cultures were incubated at 25° C., and the agar dilution plates were incubated at 20° C. the maximum production of antibiotic substance was recorded. All test organisms were inhibited, and with few exceptions in fairly high dilutions. Once again, *Sarcina lutea* was inhibited in the highest dilution, while *E. coli* showed the greatest resistance to the antibiotic substance produced.

When tryptose-phosphate broth culture and agar dilution plates were incubated at 20° C. inhibition toward the test organisms was evident in high dilutions. For the most part, production of the antibiotic substance in the broth culture incubated at 20° C. was neither greater nor less than production in the culture incubated at 25° C. On the other hand, both tryptose-phosphate broth cultures, incubated at 25° C. and 20° C., showed more production of antibiotic substance than the nutrient broth culture incubated at 25° C. The two gram positive bacteria and the fungi were inhibited at twice the dilution in which inhibition of the gram negative bacteria occurred.

SIGNIFICANCE OF RESULTS

Although the centrifuged culture broth medium, used in the agar dilution plates, appeared relatively free of organisms, the incubated agar plates showed growth of the antagonistic organisms, especially in the lower dilutions. Consequently, the most significant observation made was that, in all cases, inhibition of the test organisms was coincident with the growth of the antagonist on the agar dilution plates. Furthermore, in all series but one, heavier growth of the antagonists on the agar dilution plates, i.e., lower dilutions, resulted in the inhibition of the maximum number of test organisms.

At first, this observation suggested a possibility that inhibition of the test organisms was due primarily to overgrowth of the antagonist rather than to the production of an antibiotic substance by the antagonist. However, further observations would seem to contradict this contention. (1) In a number of instances, some of the test organisms inhibited by the antagonist at one incubation temperature were not inhibited at other incubation temperatures even though the growth of the antagonist was as heavy or heavier in the series where no inhibition occurred. (2) *Flavobacterium rigense* showed no evident growth in broth cultures when incubated at 37.5° C. and no inhibition was shown to any test organisms. Furthermore, agar dilution plates incubated at 37.5° C., but prepared from culture broths incubated at 25° C., showed a very retarded or absence of growth of the antagonist compared to similar agar dilution plates incubated at lower temperatures. Nevertheless, the agar dilution plates incubated at 37.5° C., showed inhibition to all test organisms, and all, except *E. coli,* were inhibited in dilution of 1 :100 or more.

In the writer's opinion, the observations cited above indicate that both the *B. megatherium* and the *F. rigense* produced antibiotic substances, but these substances were not separated from the organisms. Possibly other methods of treatment might have accomplished this separation.

Tables I and II are summary tables showing the maximum potency of the antibiotic substances produced in the culture broth media at the various incubation temperatures. Potency figures are expressed in terms of the maximum dilution at which inhibition of the test organism occurred.

As shown in the tables, these strains of *B. megatherium* and *F. rigense* showed rather surprising antagonism to all of the eight test organisms used. Reference to other bacteria producing antibiotic substances show that they generally tend to be specific toward certain organisms. However, the tables show clear evidence that, even though inhibition was shown to all test organisms, actually the antibiotic substances produced were specific for certain organisms when all conditions are taken into consideration.

B. megatherium showed production of an antibiotic substance at all incubation temperatures with the greatest potency occurring in cultures incubated at 37.5° C. On the other hand, *F. rigense* showed no antibiotic substance produced at 37.5° C., but it produced a more potent antibiotic substance than *B. megatherium* when cultured at 25° C. and 20° C.

At 37.5° C. incubation temperature *B. megatherium* produced the greatest inhibition to *Micrococcus catarrhalis,* a gram negative bacterium, and to *Saccharomyces pastorianus,* a fungus; while at 25° C. and 20° C., the greatest inhibition produced by *B. megatherium* was toward *Sarcina lutea,* a gram positive bacterium. On the other hand, *Serratia marcescens, Pseudomonas aeruginosa* and *E. coli,* all gram negative bacteria, showed the greatest resistance to the antibiotic substance produced by the *B. megatherium.*

F. rigense produced, at both 25° C. and 20° C. incubation temperatures, an antibiotic substance showing greatest inhibition to *Sar-*

cina lutea and *Staphylococcus aureus,* both gram positive bacteria, while the least inhibition was shown to *Serratia marcescens* and *E. coli,* both gram negative bacteria.

In general, both antagonists showed greatest inhibition to the gram positive organisms, while the gram negative organisms showed the most resistance.

Table III shows the period, in number of days, when the greatest amount of antibiotic substance was produced in the various culture broths.

Tryptose-phosphate broth cultures of *B. megatherium* showed the greatest production of antibiotic substance between 5-8 days when both broth culture and agar dilution plates were incubated at 37.5° C.; between 11-17 days when the broth culture was incubated at 25° C., and the agar dilution plates were incubated at 37.5° C.; between 9-16 days when the broth culture was incubated at 25° C., and the agar dilution plates were incubated at 20° C.; and between 3-8 days when both broth culture and agar dilution plates were incubated at 20° C.

Nutrient broth cultures of *B. megatherium* showed the greatest production of antibiotic substance between 9-14 days when both broth culture and agar dilution plates were incubated at 37.5° C.; and between 9-16 days when the broth culture was incubated at 25° C., and the agar dilution plates were incubated at 37.5° C.

Tryptose-phosphate and nutrient broth cultures of *F. rigense* showed no production of antibiotic substance when both broth cultures and agar dilution plates were incubated at 37.5° C. Tryptose-phosphate broth cultures showed the greatest production of antibiotic substance between 6-15 days when the broth culture was incubated at 25° C., and the agar dilution plates were incubated at 37.5° C.; between 6-25 days when the broth culture was incubated at 25° C., and the agar dilution plates were incubated at 20° C.; and between 3-17 days when both broth culture and agar dilution plates were incubated at 20° C.

Nutrient broth cultures of *F. rigense* showed the greatest production of antibiotic substance between 3-16 days when the broth culture was incubated at 25° C., and the agar dilution plates were incubated at 37.5° C.; and between 6-25 days when the broth culture was incubated at 25° C., and the agar dilution plates were incubated at 20° C.

B. megatherium apparently lost some of its potency through prolonged culturing on artificial media, while the potency of the *F. rigense* was not effected noticeably.

One of the test organisms, *Saccharomyces pastorianus,* showed particular evidence of being a weak strain through the culture series. The other test organisms consistently showed fairly vigorous growth, except in rare instances.

CONCLUSIONS

1. Bacteria producing antibiotic substances were isolated from the White River Canal, Indianapolis, Indiana.

2. These organisms have been identified tentatively as *Achromobacter iophagum, Bacillus megatherium,* and *Flavobacterium rigense.*

3. To the writer's knowledge no production of antibiotic substance has been reported for any of these organisms.

4. *Achromobacter iophagum* showed inhibition to only one of eight test organisms in low dilutions. On the other hand *B. megatherium* and *F. rigense* produced inhibition to most or all of the test organisms; in some cases, in fairly high dilutions.

5. *F. rigense* produced an antibiotic substance which was more potent to the eight test organisms than that produced by *B. megatherium.*

6. Broth cultures of *B. megatherium* produced the antibiotic substance at incubation temperatures of 37.5° C., 25° C., and 20° C. Tryptose-phosphate broth cultures produced more antibiotic substance than did the nutrient broth cultures, with greatest production occurring when both broth cultures and agar plates were incubated at 37.5° C.

7. Broth cultures of *F. rigense* produced antibiotic substance at incubation temperatures of 25° C. and 20° C., while none was produced at 37.5° C. Tryptose-phosphate broth cultures produced greater amounts of antibiotic substance than the nutrient broth cultures with maximum production occurring when the broth culture was incubated at 25° C., and the agar dilution plates were incubated at 20° C.

8. *B. megatherium* showed evidence of losing its potency after successive culture and incubation periods, while *F. rigense* showed no evidence of loss of potency.

9. No attempt was made to isolate the antibiotic substances from the organisms.

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The writer wishes to express his sincere appreciation to Dr. Ray C. Friesner for suggesting the problem and critical reading of the manuscript, and to William A. Daily and Fay Kenoyer Daily for their many helpful suggestions during the course of the research.

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TABLE I

Bacillus megatherium

Maximum Potency of Agar Dilution Units Versus Test Organisms

				Gram Negative				Gram Positive		Fungi	
Culture Media	Condition of Culture When Plated	Incubation Temperature Of Culture °C.	Incubation Temperature Of Agar Plates °C.	Micrococcus catarrhalis	Escherichia coli	Pseudomonas aeruginosa	Serratia marcescens	Staphylococcus aureus	Sarcina lutea	Monilia albicans	Saccharomyces pastorianus
Tryptose-Phosphate Broth	centrifuged	37.5	37.5	200	100	0	0	100	100	100	200
Nutrient Broth	centrifuged	37.5	37.5	100	10	0	0	10	10	10	10
Tryptose-Phosphate Broth	fritted glass filter	37.5	37.5	0	0	0	0	0	0	0	0
Tryptose-Phosphate Broth	centrifuged	25	37.5	25	10	10	10	25	200	25	50
Nutrient Broth	centrifuged	25	37.5	50	10	10	10	25	100	25	100
Tryptose-Phosphate Broth	centrifuged	25	20	10	0	10	0	10	50	0	25
Tryptose-Phosphate Broth	centrifuged	20	20	10	50	50	0	50	100	0	100

TABLE II

Flavobacterium rigense

Maximum Potency of Agar Dilution Units Versus Test Organisms

				Gram Negative				Gram Positive		Fungi	
Culture Media	Condition of Culture When Plated	Incubation Temperature Of Culture °C.	Incubation Temperature Of Agar Plates °C.	Micrococcus catarrhalis	Escherichia coli	Pseudomonas aeruginosa	Serratia marcescens	Staphylococcus aureus	Sarcina lutea	Monilia albicans	Saccharomyces pastorianus
Tryptose-Phosphate Broth	centrifuged	37.5	37.5	0	0	0	0	0	0	0	0
Nutrient Broth	centrifuged	37.5	37.5	0	0	0	0	0	0	0	0
Tryptose-Phosphate Broth	centrifuged	25	37.5	100	100	25	100	100	200	100	100
Nutrient Broth	centrifuged	25	37.5	10	10	0	10	10	100	10	10
Tryptose-Phosphate Broth	centrifuged	25	20	200	50	200	100	200	400	200	200
Nutrient Broth	centrifuged	25	20	100	50	50	50	200	200	50	50
Tryptose-Phosphate Broth	centrifuged	20	20	100	100	100	100	200	200	200	200

TABLE III

Occurrence of Maximum Production of Antibiotic Substance

No. of Days

Culture Broth Medium	Incubation Temperature of Culture Broth °C.	Incubation Temperature of Agar Plates °C.	Bacillus megatherium	Flavobacterium rigense
Tryptose-Phosphate Broth	37.5	37.5	5-8	
Nutrient Broth	37.5	37.5	9-14	
Tryptose-Phosphate Broth	25	37.5	11-17	6-15
Nutrient Broth	25	37.5	9-16	3-16
Tryptose-Phosphate Broth	25	20	9-16	6-25
Nutrient Broth	25	20		6-25
Tryptose-Phosphate Broth	20	20	3-8	3-17

GROWTH CORRELATIONS IN FIVE SPECIES OF DECIDUOUS TREES[1]

By CHARLES W. REIMER

Since the beginning of the present century much work has been done in America on tree growth, the greatest part of this being centered around growth exhibited by coniferous species. The literature is less extensive on growth studies of deciduous trees. MacDougal's work on radial growth with the dendrometer and dendrograph (27, 28) is too extensive for review in a paper of this type. Glock (19) has given excellent review of results from study of annular rings. Dendrometer studies on deciduous trees in the midwest have been carried out by Beilmann (2), Friesner (12, 14), and Lodewick (26). Recently Daubenmire and Peters (8) using a new type of dendrometer (7) have presented the results of comparative studies of coniferous and deciduous species in Idaho. Most of the radial growth studies has consisted of ring counting (3) (5) (6) (9) (10) (13) (18) (19) (29).

Axial growth behavior during individual growth periods has been studied in a number of genera. Kienholz (23) has shown that trees may be divided into two groups from the standpoint of duration of axial growth, viz., short season trees, in which 90% of the axial growth occurs in 30 days and the total period approximates 60 to 70 days; and long season trees, in which 90% of the axial growth occurs in 60 days and the total period approximates 110 days. *Fraxinus americana, Fagus grandifolia* and *Acer saccharum* are placed in the short season group and *Betula alba, B. populifolia, Liriodendron tulipifera* and *Acer rubrum* belong to the long season group. Friesner (15, 16) has shown that *Pinus resinosa, P. strobus, P. banksiana* and *P. sylvestris* belong to the short season group. Baldwin (1), Cook (5) and Kienholz (23) have shown that *P. resinosa* belongs to the short season group.

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[1] A portion of a thesis submitted in partial fulfillment of the requirements for the Master of Arts degree in the Division of Graduate Instruction, Butler University.

Pearson (31) found closest correlation between height growth of western yellow pine and spring rainfall, in Arizona. Cook (6) found that rainfall does not effect axial growth except in case of droughts. Hawley (21) found that axial growth in *Juniperus virginiana* showed closest correlation with rainfall of the preceding fall and winter months. Baldwin (1) found that temperature seemed to be the most important climatic factor in determining the beginning and rapidity of height growth. Cook (6) points out, however, that temperature is not of major importance after the early course of growth.

Friesner places the time for initiation of axial growth in four species of pine in Brown County, Indiana, as April 13 (1941). Baldwin shows much height growth beginning in April in conifers studied. Kienholz (23) says that in 1937 the time of bursting of leaf buds in nineteen hardwood and softwood species varied from April 20 to May 12; in 1938, from April 21 to May 2; and in 1939, from May 1 to May 12.

In most species studied the general sequence was: first bud activity, and then trunk activity. Friesner finds that cambial activity in the trunk of *Fagus grandifolia* and *Acer saccharum* at a height of about 4.5 feet begins at about the time when leaves are full size. As a general statement it might be said that axial growth precedes radial growth in deciduous trees (except *Fraxinus, Ulmus,* and *Quercus*) more so than in coniferous species where it oftentimes is the reverse.

Some dates of inception of radial growth in deciduous trees have been given by various authors:

Quercus	April 10	Beilmann (2)
Q. alba	April 21	Friesner (14)
Fagus sylvatica	Last half April	Kienholz (23)
	Late May to early June	MacDougal (27)
F. grandifolia	May 12	Friesner (14)
Acer negundo	May 19	Korstian (30)
A. saccharum	May 12	Friesner (25)
A. saccharinum	April 20, 27	Hanson and Brenke (20)
Ulmus fulva	April 21	Friesner (14)
U. Americana	April 21	Friesner (14)

Ring porous trees are said to demonstrate much earlier inception of growth than diffuse porous trees. Friesner (15) reported earlier inception of growth in Ulmus and Quercus (ring porous species) over Fagus and Acer (diffuse porous species). This would seem to agree with Hubers' (22) conclusion that "Die Wasserleitung ringporiger Gehölze geht fast ausschlieszlich in aüsersten Jahresring vor sich, erfolgt aber dafur etwa zehnmal rascher als bei den auf breiter Flache leitenden zerstreutporigen Geholzen." This would indicate that because of a more rapid rate of translocation of water in ring porous wood there would be an earlier inception of growth. A recent study by Daubenmire and Peters (8) casts some doubt as to the significance of this. They found in Ulmus and Quercus which are ring porous an almost identical inception date with Fagus which is diffuse porous. This was in an area where these trees had been introduced. It, apparently, does not hold in Indiana where they are native. Juglans which is semi-ring porous instead of beginning intermediately came later than any of the other trees. The trees studied while out of their native habitat were under identical environmental conditions.

Cessation of axial growth varies with the species studied and definite correlations have been few. Some authors find a period of dragging activity in late summer, then a final and complete stoppage of elongation. Sometimes there follows a period of post-seasonal growth in which elongation of a few millimetres is noticed.

The length of shoot growth has been attributed by Kirkwood (24) to be dependent upon the size, vigor and amount of nutritive substance stored in the terminal bud during the last season. This is an agreement with rainfall correlations for the storage season indicated by Motley (30).

Radial growth in most cases is over a longer period than axial growth. For example, Hanson and Brenke (23) gave the overall radial growth period for *Acer saccharinum* as 170-177 days inclusive. MacDougal found the duration of radial growth in *Pinus flexilis* to be 61 days. *Ulmus fulva* exhibited a radial growth season of 133 days (27); Pinus and Picea, 50 to 60 days; Tsuga, 85 days; Larix, 100 days.

Friesner (17) describes radial growth as either 1) grand period curve type or essentially so (e.g., *Fagus grandifolia*), or no resemblance to the grand period type (e.g., *Ulmus americana*). One statement from this paper, "environmental controls the quantitative but not the qualitative aspects of the behavior," describes what other papers collectively have shown.

METHODS

Five species of deciduous trees were selected for this study. They are: *Fagus grandifolia, Prunus serotina, Acer saccharum, Acer platanoides,* and *Tilia americana.* The study was carried out in two plots, the Friesner area in Brendonwood, and the Voight area. The former is located about two miles west of Ft. Harrison in the northeastern section of Marion County. The latter is located on West 10th Street and about three miles from the Marion-Hendricks County line. Four dendrometers were set up in the Brendonwood area. One each was attached to the trunks of *Tilia americana, Prunus serotina, Acer saccharum* and *Acer platanoides.* The data for the fifth species was taken from a study on the estate of Charles J. Lynn being carried out by Dr. R. C. Friesner on *Fagus grandifolia.* The dendrometers were attached to the trees at breast height by metal clamps anchored deeply into the heartwood to prevent possible miscalculations from cambial growth. A cross bar was attached to these clamps and on it the dendrometers were attached. The graduations recordable made it possible to detect an increase or decrease of .01 mm. The recording arm was set in a smoothed pit shallowed in the outer bark. Care was taken not to injure the bark cambium. Readings were taken once a week. Whenever possible the readings were taken about the same time of day so as to avoid possible inaccuracy due to daily reversible changes. The clamps holding the dendrometers were made of soft rolled steel whose coefficient of linear expansion is .0000063 in. per degree Fahrenheit. The instrument itself was made entirely of metal alloys which carry a very low coefficient of expansion.

Measurements of axial elongation were made in both areas. One hundred twigs were tagged in the Brendonwood area which will be designated as Area A. Fifty twigs were tagged in the 10th Street area which will be designated as Area B.

Weekly measurements were made with a ruler graduated in millimetres. The first few weeks measurements were taken from the base point of measurement to the tip of the swelling bud. When the bud opened it became necessary to choose another point of measurement. Thus the blank species in table II indicate the week during which no accurate measurement could be taken. The measurements after opening of the leaf bud were taken to the farthest advancing evident node. This was the most stable point for measurement and represents the closest definite area to the meristematic region. Measurements were made and recorded in both plots on the same day. A total of 4 trees of *Prunus serotina,* 2 of *Acer platanoides,* 4 of *A. saccharum,* 2 of *Tilia americana* and 5 of *Fagus grandifolia* were used for the axial measurements. Rainfall was measured weekly in each plot using a rain gauge of the United States Weather Bureau type.

In addition, rainfall data figures were taken from the United States Weather Bureau reports from stations in Marion County to see to what degree there was agreement between official data and that gathered at the point of experimentation. Data were assembled from the Holiday Park station which is located about 6 miles west of Area A, from the Weir Cook Airport station which is about 4 miles south of the West 10th Street area, and from official evaporation and temperature figures from the Climatological Data published by the U. S. Department of Commerce, Weather Bureau. These figures were averaged into weekly groups.

OBSERVATIONS AND RESULTS

The trees of area A were located in a rather level section with a fair degree of drainage. Trees 4a, 4b, 4c, 5a, and 5b were situated at the edge of an old cut (east-west) which drained the immediate area. The crown was open in most places.

Trees of area B were in an open-crowned section with good drainage. The drainage consisted of two folds of land 2-6 ft. deep. The whole area B was on a slightly higher plot of ground and would probably represent a slightly better drained and aerated section.

PRUNUS SEROTINA

Radial increase (table I) which can be interpreted as growth began on May 26, 1947 and continued until September 30. Previous to this time there were recorded alternate increases and decreases in diameter. At no time up to April 26, 1948 does the reading of total increase exceed that of the peak reached in September 1947. A total of 2.88 mm of radial enlargement were recorded for the 1947 growing season. The peak of rate of radial increase was recorded June 4. A second peak was recorded June 30. The rate was high during the entire month of June.

Axial enlargement was first evident on April 14 in numbers 81-85. After about 2 weeks of smaller increases the axial measurements on May 5 showed a great increase (table II). The figures for April 21 represent transition figures and so were omitted from the calculations. It was during this period that the terminal measuring point was changed from bud end to the farthest advancing node. Over 90% of the total elongation occurred between April 14 and June 4. The zero point was reached during the week ending June 4, no elongation being recorded for the week ending June 9. Some elongation occurred after that date in these but this was very small and the total elongation after this date did not exceed the length of the bud. After the zero point was reached in June, readings were taken with decreasing frequency. By May 5 the leaves of Prunus were between 1/2 and 3/4 full size. Axial enlargement in area A extended over a period of 8 weeks, beginning with the week ending April 14 and continuing until the week ending June 4. Radial enlargement extended over a period of 19 weeks from May 26 to September 30.

The axial growth in Prunus located in area B showed a somewhat different course of development. The initial measurements were made on these on April 14 and the first recording on April 21 just at the time of transition explained earlier. The peak of growth came during the week ending May 26. The period required for 90% of the growth was from April 21 to July 21. Not until a last check in November was there no further elongation recorded for Nos. 111-115. The peak of growth was also reached about 2 weeks after that found as the peak in trees of Area A. Twigs 141-150 also exhibited a longer period of elongation but by September they had practically reached the zero point (table II). On July 7 it was evident that next year's buds were being formed in all species studied in area B.

Acer platanoides

Inception of radial enlargement began during the week ending June 17, about 15 days later than in Prunus. The peak in rate of enlargement came during the week ending June 30 with a second peak during the week ending July 28. Radial enlargement ceased on August 4. After this time until October 20 there were recorded weekly gains and losses of varying amounts none of which ever resulted in a total radius greater than that reached on August 4. On

October 20 the dendrometer was broken and not attached again until November 24, 1947.

Axial elongation was first in evidence the week ending April 7. Measurements were to the bud tip until the week ending April 28 at which time the farthest advancing node was taken as a measuring point. The amount of growth in this species was not very great as compared with Prunus. A sharp drop in elongation was noted for the week ending May 12. This shows up to a certain extent in Prunus 1a-5a, 11a-15a. This was a week in which very little rainfall was recorded (table III), the temperature also showing a definite drop (frost being reported for two days of this week). Evaporation was relatively high (table III).

The zero point in elongation came on the week ending May 26 with only slight amounts of elongation during the following weeks. Total axial elongation up until the mid-summer zero point was over a period of 8 weeks. Total radial enlargement was over a period of 8 weeks beginning the week ending June 17 and ceasing after the week ending August 4. Total radial increase was 1.42 mm.

Acer saccharum

Radial growth in this species began during the week ending June 10, 1947. The enlargement continued until the week of August 25, a duration of 12 weeks. After August 25 the same behavior of gains and losses as found in other species is in evidence. Up to the present writing (May 10, 1948) the radius had not reached the measurement taken at the highest peak found for 1947 which indicates that radial growth had not yet started for 1948. The peak of radial growth rate was reached June 17, 1947. Two minor peaks were also recorded, one on June 30 and the other on July 14.

Axial increase in area A began April 14. In area B measurements were not taken early enough to determine exact time of begining of elongation. In area B the mid-summer zero point was reached June 4. If it were permissible to use time of elongation in area A and time of mid-summer zero point in area B, it could be said that the time of axial elongation up to the mid-summer zero point was 7 weeks, which was shorter than in either Prunus or Acer platanoides. The radial enlargement period extended 11 weeks. This is a shorter period of time for radial enlargement than was exhibited by Prunus and a longer period than was exhibited by *Acer platanoides.*

After the June 4 readings were recorded, all branches except No. 93 were cut by some unknown person. The first week after the severing of the other branches close to the trunk twig 93 increased 127 mm over the previous week. Large increases were recorded each week until July 21. Total elongation was 775.0 mm, by far the greatest amount of elongation recorded by any single twig or any combination of twigs. The new bud was formed without the previous presence of a mid-summer pause.

Tilia americana

Radial enlargement began during the week ending June 17, 1947, and continued until September 22, during which time total radial enlargement of 1.58 mm was recorded. Axial increase began in area A on April 21. The peak of rate of axial increase was reached May 19 during which time the twigs averaged an increase of 48.8 mm. The mid-summer zero point was reached during the week ending June 17, no growth being recorded for the week ending June 23. Slight gains were recorded after this date. Total growth period up to the mid-summer pause for axial growth was 9 weeks. The radial growth period extended over 15 weeks with a total enlargement of 1.58 mm.

Fagus grandifolia

Radial enlargement began during the week ending May 19, 1947, and ended during the week of August 26, a total period of 15 weeks. The total radial enlargement was 1.79 mm. This is much longer than is reported by Friesner for previous years in the same trees (15). His data gives July 15 in 1941 and June 17 in 1940 as cessation dates. The remainder of the 1947 season shows only alternating losses and gains with no net increase.

Three peaks are outstanding here in relation to growth rate. The first one came during the week ending June 16 with the registering of 0.26 mm increase. The second one was June 30 with a slightly greater amount for the week (0.27 mm). The greatest peak came July 14 with a weekly increase of 0.34 mm (table I). The total radial growth period for 1947 was extended over 15 weeks.

Axial elongation began April 7 in area A. In area B the initiation time was not certain. The peak rate of axial growth was reached the week of May 19 with an average weekly elongation of 87.2 mm. for area A. The mid-summer zero point was reached during the week ending May 26, no growth being recorded for the week ending June 4. This made a total of 8 weeks.

Rainfall charts were made of both the areas studied, and from official readings taken by the Weather Bureau. The results are presented in table III. The rainfall discrepancy is important to note both in weekly variations and in variations over a longer period of time. Temperature and evaporation data are presented in table III.

DISCUSSION

The most significant contribution of this study is the relationship between axial and radial growth. These comparative data are presented in table IV. Radial enlargement in Fagus began during the week ending May 19. This is six weeks after the inception of axial growth and comes just one week before axial growth reaches its mid-summer zero point. *Acer saccharum* was well past its peak of axial elongation when radial enlargement began during the week ending June 10. *Prunus serotina* shows radial enlargement for the first time on May 26 just one week before axial elongation had stopped. The mid-summer zero point in axial elongation was reached in *Acer platanoides* during the week ending May 26, three weeks before radial enlargement was recorded. *Tilia americana* also shows most of its axial elongation occurring before inception of radial enlargement, the axial mid-summer zero point being reached during the week ending June 17 and radial enlargement beginning during the same week. These data are shown in table IV.

It is thus rather well defined that these two types of growth are alternate. This is in agreement with Reed and MacDougal (44). They have merely indicated by straight lines the length of time of shoot growth as compared with cambial activity and root growth. In their studies shoot growth preceded cambial activity by more than one month.

The relation of time of initiation of growth with other activities of the trees agrees with results of other workers on deciduous trees (27) (14) who find the leaves from one-half to fully formed before initiating of cambial activity except in Fraxinus (27) and Quercus

(27). It is highly probable that some growth promoting substance is liberated by the reactivated meristematic region of the buds which determines at least to a certain extent the time of awakening of cambial cells.

Combined results of all dendrometer recordings (table I) showing total growth show that all five species exhibit the "grand period" type of growth. This has been previously shown for *Fagus grandifolia* and *Acer saccharum* (12) (14) but not for *Acer platanoides, Tilia americana* and *Prunus serotina. Prunus serotina* shows inception of radial enlargement well in advance of Tilia and Acer which still agrees with the work of Friesner (14) and the concept of Huber (22). Friesner's study, although not indicating in the discussion, shows that there was earlier inception of cambial activity in ring porous trees (*Quercus* and *Ulmus*) than in diffuse porous trees (*Acer* and *Fagus*). The former initiated during the week of April 21; the latter not until May 5 and May 12. There seems to be a definite correlation here with earlier cambial activity in relation to vegetative bud activity, at least in the semi-ring porous *Prunus serotina* as its leaves were about 1/2 to 3/4 full size when cambial activity began. Here again the situation in *Fagus grandifolia* must be taken into account and must serve as an explanation for their similar correlation. Further work will be necessary over a period of years to decide definitely on this point.

The peak of growth rate in Fagus and Prunus was also later than in the remaining three species. Time of cessation varied, but in Fagus (ceased 8-26) and Prunus (ceased 9-20) the periods were quite long. Fagus grew much longer in 1947 than was ever previously recorded on a dendrometer. Friesner reports nine weeks growth in 1940 and five weeks in 1941; cessations being July 15 and June 16 respectively. *Acer saccharum* on his table shows increase up to July 28. Table I gives increase in *Acer saccharum* up to August 25. During July 1947 Indiana experienced very cool weather for summer. Evaporation did not remain high at any time and rainfall was over 1 inch more than recorded in 1941. These factors would quite possibly offer an explanation for this period of extended growth since moisture was greater, evaporation was not excessive, and temperature was more nearly favorable for best growth. These factors at some time during that period influenced the rate but remained favorable enough to extend the growing season. Axial elongation in all cases follows the "grand period" type of curve and in all cases except *A. platanoides* continues for a shorter period of time than is involved in radial enlargement. All of the species used in this study may be said to belong to the "short period" group as defined by Kienholz (23).

CONCLUSIONS

1. Total days of axial elongation in deciduous trees studied in area A were as follows: *Fagus grandifolia*: 8 weeks from April 7 to May 26; *Prunus serotina*: 8 weeks, from April 14 to June 4; *Tilia americana*: 9 weeks, from April 21 to June 17; *Acer saccharum*: 7 weeks, from April 14 to May 26; *Acer platanoides*: 8 weeks, from April 7 to May 26.

2. Total days of radial enlargement in the five species studied in area A are: *Fagus grandifolia*: 15 weeks, from May 19 to August 25; *Prunus serotina*: 19 weeks, from May 26 to September 30; *Tilia americana*: 15 weeks, from June 17 to September 22; *Acer saccharum*: 12 weeks, from June 10 to August 25; *Acer platanoides*: 8 weeks, from June 17 to August 4.

3. Total radial enlargement reached for 1947 was: *Fagus grandifolia*: 1.79 mm; *Prunus serotina*: 2.30 mm; *Tilia americana*: 1.58 mm; *Acer saccharum*: 1.46 mm; *Acer platanoides*: 1.42 mm.

4. Radial activity began in all five species after the peak of axial enlargement.

5. Axial growth exhibited after a mid-summer pause in all species studied represents very probably only bud formation since the total amount of post-mid-summer-pause-elongation never exceeds the final length of the buds measured.

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TABLE I

Dendrometer Readings of Radial Enlargement

Radial Changes Recorded by Dendrometer

Period ending	Fagus grandifolia		Prunus serotina		Tilia americana		Acer saccharum		Acer platanoides	
	Cur.	Tot.	Cur.	Tot.	Cur.	Tot.	Cur.	Tot.	Cur.	Tot.
3-31-47	0.00	0.00	–.10	–.10					.08	.08
4-7-47	0.00	0.00	–.08	–.18					–.20	–.12
4-14-47	0.00	0.00	–.08	–.24	–.02	–.02	–.03	–.03	.01	–.11
4-21-47	0.00	0.00	.07	–.19	0.00	–.02	0.00	–.03	–.21	–.32
4-28-47	0.00	0.00	–.07	–.26	–.02	–.04	0.00	–.03	0.00	–.32
5-5-47	0.00	0.00	.04	–.22	–.02	–.04	–.01	–.04	0.00	–.32
5-12-47	0.00	0.00	–.04	0.26	0.04	–.08	–.02	–.06	–.04	–.36
5-19-47	.10	.10	.20	–.06	0.00	–.08	.01	–.05	.12	–.24
5-26-47	.08	.18	.24	.18	0.00	–.08	0.00	–.05	.03	–.21
6-4-47	.12	.30	.30	.48	0.00	–.08	.01	–.04	.11	–.10
6-10-47	.10	.40	.28	.76	.06	–.02	.03	.01	.10	0.00
6-17-47	.26	.66	.29	.85	.36	.34	.40	.39	.16	.16
6-23-47	.11	.77	.17	1.02	.16	.50	.11	.50	.15	.31
6-30-47	.27	1.04	.30	1.32	.25	.75	.22	.72	.51	.82
7-7-47	.16	1.20	.10	1.42	.19	.94	.16	.88	.14	.94
7-14-47	.34	1.54	.20	1.62	.18	1.12	.24	1.12	.10	1.08
7-21-47	.16	1.70	.10	1.72	.14	1.26	.08	1.20	.01	1.09
7-28-47	–.04	1.66	.18	1.90	.12	1.38	.16	1.36	.29	1.38

TABLE I—(Continued)

Dendrometer Readings of Radial Enlargement

Radial Changes Recorded by Dendrometer

Period ending	Fagus grandifolia		Prunus serotina		Tilia americana		Acer saccharum		Acer platanoides	
	Cur.	Tot.	Cur.	Tot.	Cur.	Tot.	Cur.	Tot.	Cur.	Tot.
8-4-47	.11	1.77	.08	1.98	.06	1.44	.04	1.40	.04	1.42
8-11-47	–.11	1.66	0.00	1.98	0.00	1.44	–.02	1.38	–.05	1.37
8-18-47	.11	1.77	.12	2.10	.05	1.49	.02	1.40	.01	1.38
8-25-47	.02	1.79	.08	2.18	.01	1.50	.06	1.46	0.00	1.38
9-1-47	0.00	1.79	.08	2.26	.02	1.52	–.02	1.44	0.00	1.38
9-8-47	–.06	1.73	–.01	2.25	–.01	1.51	0.00	1.44	–.01	1.37
9-15-47	0.00	1.73	.01	2.26	.05	1.56	–.08	1.36	0.00	1.37
9-22-47	0.00	1.73	.02	2.28	.02	1.58	0.00	1.36	0.00	1.37
9-30-47	.02	1.75	.02	2.30	0.00	1.58	0.00	1.36	–.05	1.32
10-6-47	–.10	1.65	–.08	2.22	–.04	1.54	–.06	1.30	–.02	1.30
10-13-47	–.02	1.63	–.04	2.18	.02	1.56	–.02	1.28	–.04	1.26
10-20-47	.08	1.71	0.00	2.18	0.00	1.56	0.00	1.28		
10-27-47			.06	2.24	–.02	1.54	.02	1.30		
11-3-47	.02	1.73	–.07	2.17	.02	1.56	.02	1.32		
11-10-47	0.00	1.73	.06	2.23	0.00	1.56	–.02	1.30		
11-17-47	–.06	1.67	–.02	2.21	0.00	1.56	–.04	1.26		
11-24-47	.01	1.68	.02	2.23	0.00	1.56	–.02	1.24		
12-1-47	–.22	1.46	0.00	2.23	–.34	1.22	–.05	1.19		
12-8-47	.18	1.64								
12-15-47	–.12	1.52							–.14	
12-22-47	–.03	1.49	–.04	2.19	–.08	1.14	–.04	1.15	–.03	
12-29-47			.02	2.21	.02	1.16	–.01	1.14	–.05	
1-5-48	.15	1.64	0.00	2.21	.02	1.18	.04	1.18	.06	
1-22-48	–.86	.78	–.34	1.87	.24	1.42	–.18	1.00	–.40	
1-29-48	–.24	.54	–.22	1.65	–.44	.98	–.04	.96	–.21	
2-3-48			.42	2.07			.08	1.04	.41	
2-16-48	.92	1.46	.21	2.28	.24	1.22	.11	1.15	.08	
2-23-48	–.02	1.44	.01	2.29	–.20	1.02	–.01	1.14	–.26	
3-1-48	.14	1.58	0.00	2.29	0.00	1.02	.01	1.15	.24	
3-8-48	0.00	1.58	–.01	2.28	–.03	.99	.01	1.16	.02	
3-15-48	–.04	1.54	.02	2.30	.13	1.12	–.06	1.10	–.02	
3-24-48			–.06	2.24	–.10	1.02	.02	1.12	–.06	
3-29-48	.04	1.58	0.00	2.24	–.10	.92	.04	1.16	–.04	
4-5-48	.01	1.57	0.00	2.24	–.10	.82	–.02	1.14	–.04	
4-12-48	.02	1.59	.03	2.27	–.04	.78	.02	1.16	.04	
4-19-48	–.04	1.55	–.01	2.26	–.08	.70	–.02	1.14	–.04	
4-26-48	0.00	1.55	.02	2.28	–.08	.62	.00	1.14	–.04	

TABLE II

Axial Elongation

	Prunus		Fagus		Acer saccharum		Tilia	Acer platanoides
Date	Area A	Area B	Area A	Area B	Area A	Area B	Area A	Area A
4-7-47	0 mm		0.06 mm		0 mm		0 mm	1.7 mm
4-14-47	5.6		1.3	1.2 mm	2.2	1.0 mm	0	4.9
4-21-47			1.7	4.9	1.0	3.7	0.37	9.0
4-28-47	15.2	1.49 mm	4.4	5.9	3.0	6.2	1.85	
5-5-47	25.7	24.6	12.9	18.6	15.1	16.8	6.3	9.8
5-12-47	15.4	21.8						2.6
5-19-47	16.8	33.8	87.2	7.9	104.9	10.3	48.8	7.1
5-26-47	9.8	40.0	2.9	0.7	47.2	0.3	18.9	1.0
6-4-47	2.3	15.3	0	1.1	20.5	0	7.9	0
6-10-47	0	15.7	0	0.3		0	0.3	0
6-17-47	0.2	18.0	0	0.4		1.3	2.0	0.76
6-23-47	0	4.3	0	0		0	0	0.26
7-7-47	0	5.7	1.7	1.2		1.2	0	1.3
7-21-47	0	0.3	0.2	0.8		0.4	0.7	0.41
9-1-47	1.0	0.4	4.1	3.9		1.1	0	0.9

TABLE III

Rainfall, Evaporation and Temperature.

	Rainfall					Temperature—Averages		
Week ending	Area A	Area B	Airport	Holliday	Evaporation	Maximum	Minimum	Mean.
4-1-47			.20 in.	.07 in.		47°F.	29°F.	38°F.
4-8-47			.89	.99	.119 in.	59	41	50
4-15-47			1.64	1.52	.101	62	39	50.5
4-21-47			.75	1.02	.123	48	32	40
4-28-47	1.45 in.	1.40 in.	1.56	1.45	.117	64	40	52
5-5-47	1.15	1.10	1.05	1.17	.101	61	47	54
5-12-47	.24	.31	.28	.21	.129	66	37	51.5
5-19-47	1.41	1.85	1.71	2.05	.184	76	56	66
5-26-47	1.57	1.30	.93	1.39	.153	72	51	61.5
6-4-47	3.40	2.38	2.31	3.09	.118	72	49	60.5
6-9-47	.86	1.66	2.95	.60	.137	81	63	72
6-17-47	.39	.36	.45	.27	.187	72	56	64
6-23-47	.35	.53	.40	.27	.155	74	58	66
6-30-47	.13	.40	.28	.41	.133	81	64	72.5
7-7-47	.07	.15	.03	.00	.193	71	59	65
7-14-47	1.49	.55	.84	1.03	.169	82	62	72
7-21-47	.50	.23	.33	1.12	.133	79	69	74
7-28-47	.18	1.23	1.13	.08	.180	81	58	69.5
8-4-47	.68	.68	1.00	1.55	.221	88	64	76
8-11-47	.07	.12	.04	.23	.202	91	68	78.5
8-18-47	2.77	2.77	2.79	2.88	.150	89	73	81
8-25-47	.07	.22	1.37	.08	.157	92	72	82
9-1-47	.43	.36	.02	1.01	.105	87	68	77.5
9-8-47	.38	.52	.53	.28	.133	87	65	76
9-15-47	1.10	1.45	1.58	1.14	.139	81	63	72
9-22-47	1.25	1.42	1.32	1.32	.135	79	54	66.5
9-29-47	.02	.03	.02	.00	.105	66	42	54
10-6-47	.12	.44	.58	.19	.092	70	45	57.5
10-13-47	.00	.00	.00	.00	.085	77	52	64.5
10-20-47	1.20	1.50	.38	1.10	.073	78	54	66
10-27-47	.94	1.75	1.19	.89	.076	77	52	64.5
11-3-47	.51	.60	.42	.57		72	45	58.5

TABLE IV

Correlation between axial elongation and radial enlargement.

	Axial Elongation			Radial Enlargement		
Species	Period	Weeks	Amount (Average)	Period	Weeks	Amount
Prunus	Apr. 14-June 4	8	92 mm	May 26-Sept. 30	19	2.30 mm
A. platanoides	Apr. 7-May 26	8	39.7	June 17-Aug. 4	8	1.42
A. saccharum	Apr. 14-May 26	7	42.3	June 10-Aug. 25	12	1.46
Tilia	Apr. 21-June 17	9	48.8	June 17-Sept. 22	15	1.58
Fagus	Apr. 7-May 26	8	87.2	May 19-Aug. 25	15	1.79

A COMPARATIVE ECOLOGICAL STUDY OF TWO FOREST STANDS IN THE ILLINOIAN DRIFT PLAIN AREA OF SOUTHERN INDIANA[1]

By JACK B. SECOR

The rather uniform till plain topography of Indiana would seem, naturally, to imply a homogeneity and uniformity in the plant cover; such, however, is not the case. Friesner (4) has indicated that the state is in a critical location in reference to the distribution and geographical limitations of numerous and varied plant species.

These vegetational differences are especially marked when forest types within the deciduous forests are involved. Potzger (16) has found that microclimatic features are of sufficient importance to vary expression in oak-hickory or beech-maple type by the mere difference of south- or north-facing ridge exposures.

Because of the critical location of Indiana in the scheme of plant distribution, numerous studies have been made of various forest cover stands throughout the state. The important eastern "flats" region of the topographically uniform Illinoian Till Plain, located in the southeastern part of the state, has not been neglected in this respect (1, 8, 12). In spite of previous work on forests located here, the two forest stands discussed in this paper seemed sufficiently different in external expression to warrant such a comparative study.

Quantitative and qualitative studies of these forest remnants have given an insight into factors controlling the ecesis and development of plant community members, and have also helped to give a better understanding of the true nature of the forest types represented in Indiana. Weaver and Clements (21) list the beech-maple and oak-hickory associations as climax in the general region under study. A committee of the Society of American Foresters (20) placed the Indiana "flats" into the beech type of forest, with the beech pure or predominating. More recent investigation, however, has led to a revision of these concepts. Deam (3) has mapped the various floral areas of the state, and Braun (1), McCoy (12) and Keller (8) have indicated that even on the Illinoian Till Plain there occurs a wide variation in forest composition. The comparative ecological study presented in this paper serves to further substantiate these findings, and may also give added information about factors controlling forest development in the area.

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[1] A portion of a thesis submitted in partial fulfillment of the requirements for the degree Bachelor of Science, magna cum laude, Butler University.

LOCATION OF THE TWO WOODED AREAS

The two forest stands are located in Jennings County, in that section of the Illinoian Till Plain known as the eastern "flats." The R. H. Deputy woods is located on the east side of road 3, 6 miles south of the junction of roads 3 and 7. This is a mature stand containing numerous large beech, many of which are dying at the top. The soil is well drained by a small stream, and is cut into by a ravine near the southwest corner. The area is fairly level, and raised about 15 feet above stream level. Mr. Deputy informed us that he has owned the tract for over 40 years, and that nothing has been cut from it during his ownership. Formerly, some black walnut and tulip poplar had been removed. The second stand, known as the A. Biehle woods, is located on the west side of road 3, 4.5 miles south of the junction of roads 3 and 7. This area is very flat and poorly drained.

GEOLOGY AND PHYSIOGRAPHY OF JENNINGS COUNTY

According to Malott (10), Jennings County belongs to the till plains section of the Central Lowland province of the United States, and is a part of the Muscatatuck Regional Slope in southern Indiana. During Pleistocene times, continental glaciation brought about physiographic modifications throughout most of Indiana, obliterating much of the erosional surface features formed after the Cincinnati Arch uplift. Of the three recognized glacial invasions (Illinois, Early and Late Wisconsin), the Illinoian was the most extensive, reaching the Ohio River, but leaving unglaciated approximately 6,250 square miles (10) in the south central portion of the state. The two lobes of the Illinoian Till Plain, which are still exposed, comprise 3,100 square miles in the eastern "flats" region, and 4,100 square miles in the western lobe (10).

The Muscatatuck Regional Slope is an upland plain developed on Silurian and Devonian formations, and a thin covering of Illinoian glacial drift has helped to smooth the preglacial relief (11).

The 1940 Soil Survey (9) indicates that the county soils are leached and belong to the Gray Brown Podzolic soils group (11). These soils are characteristic of regions with a humid, temperate climate and a forest cover. On flat or poorly drained timberland, Planosols (claypan soils) have developed, which are soils characteristic of extreme formation. These soils are identifiable through their production of "heavy" horizons in most areas, the almost impenetrable layers preventing subdrainage. They are believed to represent the extreme in profile development, and owe their character primarily to the influences of relief and time, although climate and native vegetation are of minor importance.

The most widespread soil type in the county is Clermont silt loam, characterized by its light brown color and distinctly acid reaction. Owing to the small relief and impervious lower horizons of this soil, very poor drainage is in evidence wherever it is present. Silt loam is unfavorable to the growth of crops, but its topographical uniformity makes it easy to cultivate without erosion difficulties or fertilizer loss. Soil improvements, such as liming and drainage increases, have been carried out locally.

The soils in both the Deputy and Biehle woods appear to be of the Clermont silt loam type, and the soil of the latter stand appeared to be slightly more compact.

CLIMATE AND RAINFALL

According to the 1940 Soil Survey (9), Jennings County has a typical continental climate, with hot summers and moderately cold winters. Periods of extreme cold generally last only a few days. Rainfall is fairly well distributed throughout the year, but occasional dry weather in the late summer or fall is injurious to crops. The following chart, taken from the records of the United States Weather Bureau station at Butlerville, gives a summary report of precipitation in Jennings County over a period of several years:

PRECIPITATION

Season	Total for Driest Year	Total for Wettest Year	Mean	Snow (Av. Depth)
Winter	4.83 in.	13.54 in.	11.30 in.	19.6 in.
Spring	5.13	15.69	13.68	4.8 in.
Summer	11.68	13.38	12.18	0.0 in.
Fall	6.11	18.75	10.31	1.1

The average frost-free season extends from April 26 to October 14, a period of 171 days. Records are available, however, which indicate that frost has occurred as late as May 26, and as early as September 16. Injury from frost is greater in the lowlands than on the higher ground.

METHODS

This study is based upon data obtained from forty-five 100-square-meter quadrats, soil moisture percentages available from weekly soil samples, and from weekly evaporation figures collected at eight stations set up in the two stands.

Quadrats were run in two parallel sectors, 10 meters apart. A total of 25 quadrats were taken in the Deputy woods, and 20 in the Biehle stand. Quadrats were laid out by means of a cord with loops ten meters apart, and the loops were slipped over stakes to form the corners of the areas to be recorded. A skip of ten meters separated each quadrat.

Wooden calipers were used in making the DBH. measurements. All stems over one inch in diameter were measured and recorded. Stems with a diameter of less than one inch and one meter or more in height were also counted. The quadrat study was made on February 1, 1947 (table I).

Three one-eighth acre quadrats were taken in a similar manner on December 13, 1947, one in the Deputy woods and two in the Biehle woods. Results of these quadrat surveys are presented in table II. Tables include diameter size-classes, frequency index, basal area, basal area per acre (approx.), and abundance. Stems under one inch DBH. were not included in the basal area computations, but were presented to show what is occurring in the dynamics of reproduction.

Weekly evaporation was obtained by means of eight Livingston clay bulb atmometers. Four atmometer stations were established in each woods. Stations A, B, C and D were located in the Deputy woods, and E, F, G and H in the Biehle stand. In the Deputy woods, the atmometers were placed firmly in the ground in various areas of predominant beech consociations throughout the stand. The Biehle stations were set up in the following areas:

Station E—Under a large pin oak.
Station F—Under a large beech.

FIG. 1 WEEKLY EVAPORATION

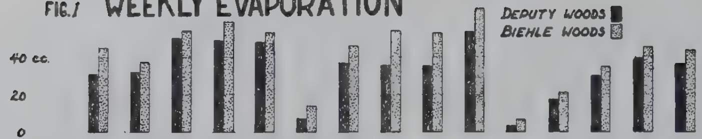


FIG. 2 DEPUTY WOODS (SOIL MOISTURE & RAINFALL)

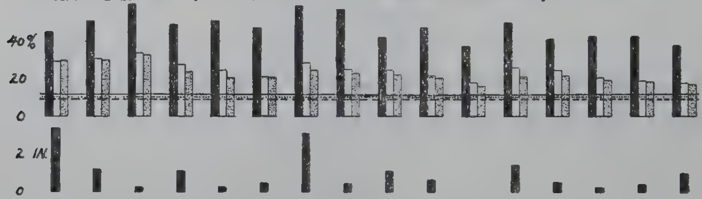
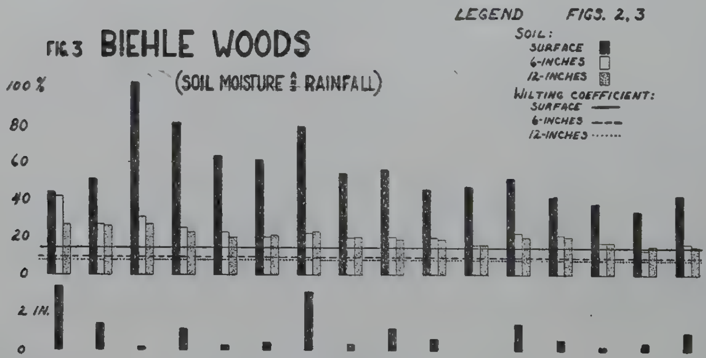
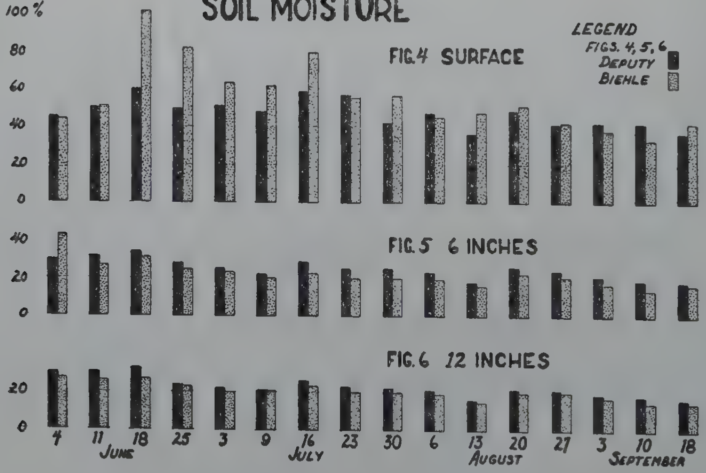


FIG. 3 BIEHLE WOODS (SOIL MOISTURE & RAINFALL)



SOIL MOISTURE



Station G—Under a sweet gum.
Station H—In a beech opening.

Atmometers were re-filled on successive weeks from June 4 to September 18, 1947. In figure 1, the weekly water losses have been averaged in each tract, and a comparison made of weekly evaporation in the two stands.

Weekly soil samples were also taken, two sets at each station. Two samples were obtained at each level (surface, 6-inch, 12-inch). These were weighed in the laboratory, placed into the oven for a suitable period (72 hours), and then removed and reweighed to determine the percentage of soil moisture. Figures 2 and 3 indicate the average weekly soil moisture in each woods at the three levels, as correlated with weekly rainfall in the area. Figures 4-6 compare these soil moisture percentages in both tracts at each level (surface, 6-inch, 12-inch).

Wilting coefficients of the three soil horizons were also included in the computations, and are presented in table IV. The wilting coefficient was obtained according to the method proposed by Briggs and Shantz.

The pH of each horizon was determined through the use of a Beckmann pH meter. These pH readings, together with the active acidity, are presented in table III.

Soil organic matter percentages were determined by the loss-on-ignition method, as described by Weaver and Clements (21) (table V).

OBSERVATIONS

Quadrat Study

Twenty-three different woody species were recorded in the Deputy woods survey. These could be grouped according to stem height as: 12 tall trees, 8 small trees, 2 shrubs, and 1 liana. The 23 woody species found in the Biehle woods could be designated as: 12 tall trees, 6 small trees, 2 shrubs, and 3 lianas.

The dominant tall tree species in the Deputy tract, in their decreasing order of importance according to basal area, are as follows: *Fagus grandifolia* (20,312 sq. in), *Acer saccharum* (1,301 sq. in.), *Liquidambar styraciflua* (708 sq. in.), and *Liriodendron tulipifera* (283 sq. in.) (table II). *Acer saccharum* and *Fagus grandifolia* show the highest frequency (100%), followed by *Carya ovata* (68%), *Liquidambar styraciflua* (48%), *Fraxinus americana* (44%), and *Ulmus americana* (44%) (table I).

Other woody species showing high frequencies are: *Asimina triloba* (60%), *Cornus florida* (52%), *Prunus serotina* (50%), and *Sassafras albidum* (44%) (table I).

In the Biehle woods, the dominant tall tree species are: *Fagus grandifolia* (6,592 sq. in), *Quercus borealis* v. *maxima* (2,961 sq. in.), *Liquidambar styraciflua* (1,872 sq. in.), *Acer rubrum* (1,261 sq. in.), and *Nyssa sylvatica* (442 sq. in.) (table I). *Fagus grandifolia* and *Carya ovata* showed the highest frequency among the tall tree species (95%), followed by *Nyssa sylvatica* (65%), *Liriodendron tulipifera* (60%), *Liquidambar styraciflua* (55%), and *Acer rubrum* (55%) (table I).

High frequencies were also recorded for *Lindera benzoin* (80%), *Asimina triloba* (60%), *Fraxinus americana* (55%), and *Smilax* spp. (50%).

Acer saccharum showed the greatest abundance of stems below one inch DBH. in the Deputy woods. *Acer* totalled 870 stems, and was followed distantly by *Fagus grandifolia* (263) and *Asimina triloba* (131). A total of 1,580 small stems were recorded in the Deputy tract.

In the Biehle stand, greatest stem abundance below one inch DBH. was exhibited by *Asimina triloba,* which had a total of 207 stems. *Asimina* was followed by *Fagus grandifolia* (53), *Carya ovata* (53), and *Fraxinus biltmoreana* (43). A total of 746 small stems were recorded, indicating that approximately 932 stems would have been counted if 25 quadrats had been taken, as in the Deputy stand.

In total abundance, *Acer saccharum* (935) and *Fagus grandifolia* (321) are predominant in the Deputy woods, but in the Biehle tract the small tree (or shrub) *Asimina triloba* records highest abundance (221), followed by *Fagus grandifolia* (82), *Fraxinus biltmoreana* (51), *Fraxinus pennsylvanica* (38), *Nyssa sylvatica* (36), and *Liriodendron tulipifera* (30).

The one-eighth acre surveys indicate that Fagus is predominant in basal area in both the Deputy and Biehle stands, with *Liquidambar styraciflua* high in this respect in both tracts. *Acer rubrum* is prominent in the Biehle woods, but its presence is negligible in the Deputy stand (table II).

EDAPHIC FACTORS

Highest soil moisture content occurs in the surface layer (figures 2-4). This is especially noticeable in the Biehle woods. Generally, soil moisture decreases with increasing depth, although the differences are not great, and in some instances, as in the Biehle tract, the 12-inch layer showed slightly more moisture content than the 6-inch at certain periods (figure 3). Results further indicate that there is very little correlation between rainfall and soil moisure, except in cases of extreme weekly precipitation (figures 2 and 3).

Figures 4-6 show that, with the exception of the surface layer, the Biehle woods generally recorded lowest soil moisture throughout the entire period of observation. Soil at 6-` and 12-inch depths was marked by absence of erratic sudden changes so prevalent in the surface horizon. Soil moisture relations were favorable for the entire season, since available water never dropped below the wilting coefficient (figures 2 and 3). Wilting coefficient figures indicate that the Deputy woods is slightly higher at all soil horizons (table IV).

The soils were found to be slightly acidic (table III), but very little variation was observable either between tracts or between horizon levels. Results of organic content tests show that while there are slight differences in the forest stands at the three levels, these differences do not appear to be sufficient to have directly caused the vegetational variations in the two areas (table V).

EVAPORATION

Results (figure 1) indicate that evaporation was higher in the Biehle stand during the entire period of observation. Both tracts followed, rather closely, the same evaporational fluctuations, and the high for the two stands was recorded on August 13, 1947.

DISCUSSION

Quadrat Study

Deputy Woods

The more recent work of McCoy (12) and Keller (8) in the "flats" region of Indiana has led to an hypothesis that the forests in this area represent mixed-mesophytic transitional types between the flood plain and near climax formations. The results of this survey appear further to substantiate this conclusion regarding the transitional nature of the Illinois Till Plain forest, and may also aid in the emphasis of certain factors only briefly discussed in previous papers.

From the survey results, one might assume that the Deputy woods is a more or less climax formation as described by Friesner and Potzger (18) for the central Indiana area, with Fagus dominant and *Acer saccharum* in an inferior position but eventually gaining co-dominance, and becoming associated, with Fagus. However, as previously noted, many of the larger Fagus appear to be in a decadent condition, possibly as a result of a lowering of the water table, since the soil is well-drained by a small stream, and is cut into by a ravine near the southwest corner. This has resulted in dessication of the crown cover and entrance of numerous other tall tree species possibly heretofore barred from participation because of light conditions.

The great number of small stems counted (1,580) also definitely points to a woods which has by no means reached the climax stage. Potzger (14) has found that a mature forest supports less than 300 stems per acre, and the Deputy stand has a considerably higher number. Potzger, Friesner, and Keller (19) found that in a forest primeval, a well-developed small tree understory is lacking, and the shrub layer is dominated by one species, *Asimina triloba*. Table I indicates that *Asimina triloba* is prevalent, but that a definite small tree layer is in the process of development.

The high frequency of Fagus and Acer (100%) gives indication that both may form the climax association. The great number of *Acer saccharum* stems, especially in the smaller size classes, bears out the findings of Potzger and Friesner (18), who noted that Acer often greatly outnumbered Fagus in stem totals, but that a majority of the stems were less than one inch in diameter. This would seem to indicate that Acer has excellent reproductive powers, but that its mortality is high as evidenced by the lack of larger stems. Representation of Fagus in small stem size-classes, however, is greater than previously noted (18), giving further indication that *Acer saccharum* and *Fagus grandifolia,* allied with certain other mesophytic tree species (13), may eventually reach the climax condition if left undisturbed.

Biehle Woods

Results of quadrat studies (table I) indicate that the Biehle stand probably closely approximates the Deputy tract in age, with vegetational differences possibly resulting from the action of man, as well as from various edaphic and topographic factors to be discussed later. This observation is based upon the number of stems over 20 inches DBH (table I). The Deputy tract shows the greatest number of stems above this figure but species representation in this class is greater in the Biehle stand.

It is interesting to note that Fagus is again a prominent species, although the area is poorly drained, and from a casual inspection appears to present edaphic factors quite different from those prevalent in the Deputy stand. This characteristic of Fagus to ecese in a wide range of habitats under abundant moisture conditions has been noted by McCoy (12) in his study of the "flats," and by Potzger (15) for the flood-plain and north-facing slopes of flanking uplands in the Salt Creek Valley in Monroe County, Indiana.

The complete absence of *Acer saccharum* is noticeable, its place in the association being taken by *Acer rubrum* (table I). The adaptability of *Acer rubrum* to variable edaphic conditions is brought out in McCoy's (12) study of the area.

Quadrat surveys of both areas show them as stands which, while containing mature tall tree species, are still in the process of development and succession.

EDAPHIC FACTORS

Soil moisture percentages (figures 2-6) and wilting coefficients (table IV) indicate the possible importance of edaphic factors as controlling and regulating elements in a plant community. Other soil moisture studies have been carried out in the state, especially in connection with microclimate as it effects Fagus-Acer and Quercus-Carya communities (6, 16), and Tsuga and Tsuga-Pinus forest associations (7). While soil moisture is probably of prime importance as a controlling factor in the "flats" area, results indicate that the surface layer may be the most "critical" soil horizon in this respect. Figures 5 and 6 show that the poorly-drained Biehle stand had a slightly lower water content at the 6- and 12-inch horizons, whereas in the surface layer this same area had considerably higher moisture content throughout most of June and July, 1947 (figure 4).

This would seem to indicate that soil moisture alone is not the controlling edaphic factor in ecesis, but that drainage and soil structure also are of equal importance. From a visual inspection of the soils, it was observed that the Biehle 6- and 12-inch horizons exhibited more compactness. Since the two stands showed only slight variation in organic content (table V), it appears likely that soil structure also plays its part in the ecesis of woody species in the "flats" area.

Daubenmire (2) states that colloidal structure, resulting in aggregates, is quite essential for plant growth, since it makes the soil permeable to water, air, and rootlets, while at the same time giving it high water- and nutrient-holding capacities. Because of the poor drainage and compact condition of the clay soil in the Biehle woods, the entrance or runoff of surface water is retarded; consequently, a large proportion of this water remains on or in the upper soil layer, from which it is slowly removed through evaporation and any slight surface drainage available. The presence of this surface water, especially in the spring and early summer, combined with an inadequate oxygen supply for the roots, perhaps prevents the entrance and ecesis of woody species requiring a more mesophytic habitat, particularly *Acer saccharum.*

Friesner and Ek (5), in their study of microclimate and species distribution in Shenk's woods, felt that soil aeration was probably the critical factor limiting *Acer saccharum.* Friesner and Potzger (18), while surveying central Indiana forests, noted that *Acer saccharum* ranges from mesophytic to drier habitats, but rarely invades, with success, more hydrophytic areas. Their observations, combined with the findings of this survey, make it seem improbable that *Acer sac-*

charum will ever invade the Biehle stand as long as drainage and soil conditions remain as they are at present.

PH readings show that the soils are acid, but that very little variation is present in the horizons of the two contrasted stands. It is possible, however, that this acid condition may have an effect upon soil structure, since Daubenmire (2) states that often, where forest soils are acid, there is a rather slow conversion of organic debris into humus.

Weekly rainfall apparently had no striking effect upon soil moisture, except when precipitation totalled 1.5-2.0 inches or more (figures 2 and 3). Potzger (15) observed this same condition in various forest tracts throughout Monroe County, Indiana.

EVAPORATION

Weekly evaporation was greater in the Biehle stand (figure 1). It should be remembered, however, that these figures do not give a complete picture of crown cover evaporation, but are more suitably indicative of the shrub and young tree strata. Potzger (17) found that air currents are probably the most important single factor in controlling and regulating forest humidity. In his study of mosses, Potzger noted that localities with dense shrub layers, especially at forest borders, suffered less water loss than comparable areas where shrub under-stories were wanting. The Deputy woods lacked a well-developed shrub layer, but the great number of young trees might have a similar modifying effect upon the surrounding atmosphere.

SUMMARY AND CONCLUSIONS

1. Presented in this paper are results of a comparative ecological study of two forest stands in Jennings County, situated in the Illinoian Drift Plain area of southern Indiana.

2. Results are based upon 100-square-meter quadrat studies, one-eighth acre quadrats, soil acidity, soil moisture and organic content, wilting coefficients and evaporation data.

3. The Deputy stand, situated in a well-drained area, has a crown cover controlled primarily by Fagus. Many of the larger Fagus, however, are in a decadent condition, which possibly has allowed for the entrance and establishment of numerous other tall tree species. These are represented in the smaller size classes, with *Acer saccharum* high in this respect. Fagus is also high in number of young stems.

4. Indications are that, if not disturbed, the Deputy woods will reach the climax condition with *Fagus grandifolia* and *Acer saccharum* as dominants in the vegetation.

5. In the poorly-drained Biehle stand, the crown cover is dominated primarily by Fagus, but with *Quercus alba, Q. borealis maxima, Nyssa sylvatica, Liquidambar styraciflua,* and *Acer rubrum* showing prominently in the quadrat survey. *Acer saccharum* is absent, being replaced by *Acer rubrum.* Fagus is high in number of young stems.

6. Soil moisture data indicate that the surface horizon may be the most "critical" soil layer in this respect.

7. Weekly rainfall had no decided effect upon soil moisture, unless precipitation totalled 1.5-2.0 inches or more.

8. The pH readings show that the soils in both woods are acid, but that very little variation occurs between the two tracts or the three horizons (surface, 6-inch, 12-inch).

9. In 1947, soil moisture was sufficient in both areas for plant growth, since it never dropped below the wilting coefficient at any time during the 4-month survey.

10. Evaporation data show the Biehle area as having the greatest weekly water-loss, and both stands followed the same weekly evaporational fluctuations. It seems likely that the rather dense under-story of small trees in the Deputy woods reduced evaporation in that area.

11. Organic content tests suggest that soil structure rather than organic content is of primary importance in the ecesis of woody species in the "flats" area.

12. Soil survey figures point to drainage, soil aeration, and surface moisture as predominantly influencing the entrance and ecesis of various tree species, especially *Acer saccharum;* therefore, it seems likely that as long as drainage and soil structure remain as they are at present in the Biehle stand, *Acer saccharum* will not successfully invade this area.

13. These two forest stands have provided important comparative information on certain edaphic factors which seem to exert a regulatory influence over the vegetational dynamics of the area. It is felt that, if left undisturbed, these tracts will offer interesting supplementary ecological facts at a later date.

ACKNOWLEDGMENT

The writer is grateful to Dr. Ray C. Friesner for his suggestion of the problem, and to Dr. J. E. Potzger for his aid in organizing the study and his constructive criticism of the manuscript. He also expresses thanks to Dr. Friesner and students Charles Don Griffin, Robert Harmon, John Stephens, and Jack Witte for their aid in laying out the quadrats and in making the tabulations.

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TABLE I

Stems in 25 100-sqm. quadrats in Deputy Woods (D) and 20 100-sqm. quadrats in Biehle Woods (B).

Species		Below 1″	1	2	3-5	6-10	11-15	16-20	Over 20	Total stems above 1″	F. I.	Basal Area sq. in.	Basal Area per Acre sq. in.
Acer rubrum	D	1									4		
	B	7	1	2	8	4	1	2	1	19	55	1261.9	2523.8
A. saccharum	D	870	43	16	2			3	1	65	100	1301.1	2081.8
	B												
Aralia spinosa	D												
	B	17	9							9	10	7.1	14.1
Asimina triloba	D	131	13	3						16	60	19.6	31.4
	B	207	13		1					14	60	17.3	34.5
Carpinus caroliniana	D	10		1						1	16	3.1	5.0
	B												
Carya ovata	D	23	1	1						2	68	3.9	6.3
	B	53	14	7	5	1				27	95	157.0	314.1
Celtis occidentalis	D	8									24		
	B												
Cornus florida	D	27	3							3	52	2.4	3.8
	B		1							1	5	0.8	1.6
Fagus grandifolia	D	263	4	1		1	10	13	29	58	100	20312.9	32500.7
	B	53	4		1		6	11	7	29	95	6592.2	13184.3
Fraxinus americana	D	45		1						1	44	3.1	5.0
	B	12	3							3	55	2.4	4.7

TABLE I—(Continued)

Stems in 25 100-sqm. quadrats in Deputy Woods (D) and 20 100-sqm. quadrats in Biehle Woods (B).

Species		Below 1"	1	2	3-5	6-10	11-15	16-20	Over 20	Total stems above 1"	F. I.	Basal Area sq. in.	Basal Area per Acre sq. in.
F. biltmoreana	D	5	2		2					4	20	15.7	25.1
	B	43	8							8	35	6.3	12.6
F. pennsylvanica	D												
	B	38									35		
Juniperus virginiana	D	22									36		
	B												
Lindera benzoin	D												
	B	207									80		
Liquidamber styraciflua	D	32	2						1	3	48	708.3	1133.3
	B	5			2	1	6	1	2	12	55	1872.0	3744.1
Liriodendron tulipifera	D	4						1		1	12	283.5	453.6
	B	26	3			1				4	60	80.9	161.8
Morus rubra	D	5									16		
	B	4									15		
Nyssa sylvatica	D	6									12		
	B	22	2	1	4	6	1			14	65	442.1	884.2
Ostrya virginiana	D	1									4		
	B												
Prunus serotina	D	35	5	1						6	50	7.1	11.3
	B	1									5		

TABLE I—(Continued)

Stems in 25 100-sqm. quadrats in Deputy Woods (D) and 20 100-sqm. quadrats in Biehle Woods (B).

Species		Below 1"	1	2	3-5	6-10	11-15	16-20	Over 20	Total stems above 1"	F. I.	Basal Area sq. in.	Basal Area per Acre sq. in.
Quercus borealis	D	10	2	1						3	32	14.1	22.6
v. maxima	B								4	4	25	2962.0	5924.0
Q. alba	D												
	B	3			1	1	1			3	25	224.6	449.7
Rhus radicans	D	1									4		
	B												
Rubus sp?	D												
	B	1									5		
Sambucus canadensis	D	3									12		
	B	4									10		
Sassafras albidum	D	20	2	1		1				4	44	33.0	52.8
	B	25									35		
Smilax sp?	D	25									24		
	B	120									50		
Ulmus americana	D	33	12	2	1					15	44	22.8	36.4
	B	2	1		1					2	20	7.9	15.7
Vitis sp?	D												
	B	2	1	1						2	5	3.9	7.9

TABLE II

Results of two one-eighth acre areas in Biehle Woods (B) and one one-eighth acre area in Deputy Woods (D).

Species		Below 1"	1	2	3-5	6-10	11-15	16-20	Over 20	Total Stems 1" and Above	Approx. Basal Area Per Acre (Sq. In.)
Acer rubrum	B	3	1	3	13	7			1	25	3,844.57
A. saccharum	D	346									
Asimina triloba	B	53									
	D	102									
Aralia spinosa	B	3									
Carpinus caroliniana	D	7									
Carya ovata	B	20	3	4	1	3				11	568.52
	D	3									
Cornus florida	B	1									
Evonymus atropurpureus	B	1									
Fagus grandifolia	B	35	2	1			2	7	3	15	13,012.06
	D	14				3	3	3	5	14	30,373.5
Fraxinus americana	B	25			1					1	50.26
	D	14									
Lindera benzoin	B	366									
Juniperus virginiana	D	1									
Liquidambar styraciflua	B				2	9				11	2,296.07
	D	4							1	1	4,579.6
Liriodendron tulipifera	B	4	2		1					3	84.80
	D	1									
Morus rubra	B	3									
	D	2									
Nyssa sylvatica	B				1					1	78.52
Ostrya virginiana	B	4									
Quercus prinus	B					1				1	201.02
Q. palustris	B					1				1	201.02
Sambucus canadensis	B	2									
	D	3									
Sassafras albidum	B	8									
	D	1									
Smilax sp.?	B	30									
Ulmus americana	B			1	1					2	62.82

TABLE III

Soil Acidity in terms of Active Acidity (A) and pH (H).

		Deputy Woods Stations					Biehle Woods Stations				
Soil Levels		A	B	C	D	Av.	E	F	G	H	Av.
Surface	A	12.5	11.9	8.0	8.2	10.14	8.6	18.1	5.6	16.1	12.12
	H	5.90	5.95	6.12	6.09	6.0	6.07	5.75	6.24	5.80	5.92
6-inch	A	7.1	8.4	17.9	10.1	10.87	7.7	8.3	10.8	11.1	9.46
	H	6.14	6.08	5.75	6.01	5.97	6.10	6.09	5.97	5.96	6.03
12-inch	A	10.7	8.2	15.9	11.7	11.62	9.5	9.2	10.16	11.7	10.14
	H	5.97	6.09	5.80	5.93	5.94	6.03	6.04	6.00	5.93	6.00

TABLE IV

Wilting Coefficients in percentages.

	Deputy Woods Stations					Biehle Woods Stations				
Soil Levels	A	B	C	D	Av.	E	F	G	H	Av.
Surface	12.60	11.81	13.76	12.55	12.68	13.27	11.11	14.22	10.20	12.20
6-Inches	10.63	9.43	10.13	8.96	9.78	9.01	8.20	8.33	9.56	8.77
12-Inches	11.18	10.71	10.00	8.84	10.18	8.44	8.28	8.08	8.78	8.39

TABLE V

Organic content of the soil in percentages.

	Soil Levels		
Forest Stands	Surface	6-Inches	12-Inches
Deputy	7.74	3.67	2.77
Biehle	8.63	3.32	2.80

AN ECOLOGICAL SURVEY OF THE CRAWFORD WOODS, CLARK COUNTY, INDIANA

By JACK B. SECOR

Numerous surveys of forested areas throughout Indiana have yielded a wealth of ecological knowledge, especially in regard to factors controlling and regulating the invasion and ecesis of deciduous tree species making up these forest formations. Perhaps no other area in the state has undergone a more intense study by ecologists than the Illinoian Drift Plain region, located in the southern part.

The Illinoian Drift Plain in Indiana includes that region of the extensive Illinoian glaciation not covered by the two succeeding Wisconsin ice sheets. This area is composed of two prongs extending into the southern portion of the state; an eastern lobe of 3,100 square miles, and a western lobe comprising 4,100 square miles (5).

The topographical uniformity of the Illinoian Drift Plain had previously led to certain misconceptions regarding forest types in the area. The idea of a homogeneity of forest cover throughout the two lobes has since been dispelled by the more recent work of Braun (1), Keller (4), and McCoy (6), who noted the variable nature of the forest stands. Keller (4) believes that these stands represent transitional types of the mixed-mesophytic forest in various stages of development from the approximate flood-plain type of forest to the near climax formations.

In a region where topography is uniform but forest stands differ in their species composition, it has become apparent that micro-climatic factors exert a controlling influence. Variations in drainage and soil structure have been used to explain forest cover changes, and the author, from recent work in the area, has come to feel that these plus soil surface moisture are probably predominant in influencing the entrance and ecesis of various tree species (9).

This paper deals with a survey of another forest stand in the Illinoian Drift Plain. The author hopes that it may add to our increasing understanding of the forest types represented in this area.

LOCATION

The Crawford woods is located in Clark County, Indiana, one mile south of the town of Solon. Clark County is included in the southern-most tier of Indiana counties bordering the Ohio River, and most of it is situated in the eastern lobe of the Illinoian Drift Plain. The terrain of the area studied is very flat, thus affording little or no drainage.

SOIL FEATURES

The soil of the Illinoian Drift Plain area is rather uniform, and the typical soil structure is a compact, whitish clay. This clay soil generally becomes compact at the surface and forms a hardpan layer beneath. Subsoil drainage is hindered by the fine texture of the soil and the presence of this hardpan layer. The author's previous study of soil moisture in the area, in which he compared a well and a poorly drained forest stand (9), has led him to feel that the surface horizon is probably the most "critical" in controlling the ecesis of certain species, since only in the moisture content of this soil layer (moisture content of 6- and 12-inch horizons was also determined) did the inadequately drained stand greatly differ from the well drained tract.

METHODS

This study is based upon data obtained from twenty-five 100-square-meter quadrats. Quadrats were run in two parallel sectors, 10 meters apart. These were laid out by means of a stout cord with loops ten meters apart, the loops being slipped over stakes to form the corners of the areas to be recorded. A skip of ten meters separated each quadrat.

Wooden calipers were used in making the DBH. measurements. All stems one inch or over in diameter were measured and recorded. Stems with a diameter of less than one inch but one meter or more in height were also counted. Results of this quadrat survey are presented in tables I and II. Tables include diameter size-classes, frequency index, basal area, basal area per acre (approx.), and abundance. Basal area computations do not include those stems under one inch DBH., which are presented simply to show what is occurring in the dynamics of reproduction. The quadrats were taken in January, 1947.

OBSERVATIONS

In the Crawford woods survey, 23 different woody species were recorded. These included 14 tall trees, 4 small trees, 2 shrubs, and 3 lianas.

A study of table I indicates almost total control of the crown cover by *Fagus grandifolia.* Fagus is far ahead of any other tall tree species in total basal area (17,887 sq. in.), being very distantly followed by *Carya ovata* (1,220 sq. in.), *Nyssa sylvatica* (713 sq. in.), and *Liquidambar styraciflua* (486 sq. in.).

Fagus also leads in frequency (100%), followed by *Carya ovata* (80%), *Nyssa sylvatica* (80%), and *Liquidambar styraciflua* (76%) (table I). *Fagus grandifolia* is the only tall tree species showing high representation in all stem-diameter size classes. Nyssa and Liquidambar are also present in a majority of the stem-diameter classes, but their quantity does not nearly equal that of Fagus in most cases, especially when the higher diameter categories are checked (table I).

Fagus again shows prominently in stem abundance below one inch DBH., with a total of 171 stems counted. In this respect, Fagus is followed by *Fraxinus americana* (109), *Liquidambar styraficlua* (97), *Nyssa sylvatica* (92), and *Carya ovata* (49) (table I). *Fraxinus americana* makes a good showing in this small stem category, but is entirely absent in the larger diameter classes.

A total of 877 stems were recorded in the 25 quadrats taken in the survey. It is interesting to note that *Acer saccharum* is not present, and that *Acer rubrum* is only sparsely represented in the survey results (table I). *Fagus grandifolia* is by far the most prominent tall tree species encountered, leading in basal area, frequency, abundance, and most of the stem-diameter classes (table I).

DISCUSSION

Upon a perusal of the Crawford woods survey results, one immediately notices the almost complete dominance of the crown cover by *Fagus grandifolia.* McCoy (6) and Keller (4) had previously noted the great abundance of this species in poorly-drained regions such as the Crawford woods, as well as in more mesophytic habitats where soil moisture conditions are still adequate for its growth and reproduction.

The high frequencies of Nyssa, Liquidambar, and *Carya ovata* are quite in line with results of previous studies in the area (4, 6), especially in the more poorly-drained regions. *Acer rubrum* has also been shown to occur prominently in the forest cover, but its presence in the Crawford woods is negligible, even though the level terrain presents ideal conditions for the establishment of this species.

It is interesting to note that *Fraxinus americana* is high in number of young stems, but is completely absent from the larger stem-diameter classes (table I). Three factors, acting singly or as a unit, may explain the apparent deficiency of this and other species in the larger stem-size brackets. These are: (1) good germination but a high mortality rate, (2) intolerance after the initial stages of growth, and (3) the possibility that these species are late invaders of the area. Weaver and Clements (10) state that various woody species tend to remain tolerant during the early growth years, but lose this ability and drop from competition with maturation. Griffin (3) has concluded that in a flood-plain forest, where soil moisture is always adequate, elimination of stems is largely the result of the light factor. Since the poorly drained Crawford woods apparently does not lack for sufficient soil moisture throughout the growing season, it seems entirely likely that the light factor does play a part in eliminating certain tall tree species from a place in the crown cover. The high mortality of certain species, particularly *Acer saccharum,* has been previously noted by Potzger and Friesner (8), who found Acer to show excellent germinative powers, but greatly reduced ability to develop into the mature tree.

McCoy (6) and Keller (4) observed the absence of *Acer saccharum* from the more poorly drained forest sites. Potzger and Friesner (8), while surveying central Indiana forests, noted that *Acer saccharum* ranges from mesophytic to drier habitats, but rarely invades, with success, more hydrophytic areas. Friesner and Ek (2), in their study of micro-climate and species distribution in Shenk's woods, felt that soil aeration was probably the "critical" factor limiting the distribution of *Acer saccharum.* The author in a recent survey of two contrasted forest stands in the Illinoian Drift Plain (9), has also come to feel that drainage, soil structure (including soil aeration) and surface moisture are the most important conditions delimiting the presence of this species in the area. Keeping these points in mind, it seems likely that considerable modification in drainage and soil structure would have to occur before *Acer saccharum* could successfully invade the Crawford stand.

The fact that only 23 different species were recorded is further indicative of the rigorous micro-climatic factors controlling species distribution throughout the Illinoian Drift Plain. McCoy (6) lists from 18 to 30 species, Keller's Klein woods survey (4) also disclosed 30 species, and the author's previous quadrat study (9) showed only 23 species. In contrast, Potzger and Friesner (8), in their study of central Indiana forests, listed 61 species in the Acer-Fagus type of forest, and 58 species for the Quercus-Carya type.

An examination of the survey results indicates that the Crawford woods is not a virgin stand, but rather is in a mature stage of secondary succession. Potzger (7) has found that a mature forest supports less than 300 stems per acre, and the Crawford stand, with a total of 877 stems counted in only 25 quadrats, has a considerably higher number. Viewing the almost absolute dominance of Fagus in the Crawford stand, and its apparent stability in the formation as evidenced by the number of young seedlings and excellent representation in all stem diameter classes, it seems likely that the edaphic modifications presented above will definitely have to occur before the true Acer-Fagus climax can be attained.

SUMMARY AND CONCLUSIONS

1. Presented in this paper are results of an ecological study of the Crawford woods, a forest stand situated in the Illinoian Drift Plain area of southern Indiana.
2. Results are based upon twenty-five 100-square-meter quadrats.
3. The Crawford woods, a level area with little or no drainage, has a crown cover almost completely dominated by *Fagus grandifolia.* Among the tall tree species, Fagus leads in basal area, frequency, abundance, and most of the stem-diameter size classes (table I).
4. Other tall tree species appearing to a lesser extent in the crown cover, but showing high frequencies, are *Carya ovata, Nyssa sylvatica,* and *Liquidambar styraciflua.* Nyssa and Liquidambar are present in many of the stem-diameter divisions, but their presence, in quantity, is limited to the smaller classes.

5. *Fraxinus americana* is high in number of stems below one inch, but is absent from the larger stem-diameter classes. There is a possibility that this species is a later invader in the Drift Plain area, requiring edaphic modification before it is able to successfully invade and ecese. It is also suggested that a high mortality rate and intolerance after the initial stages of growth may be factors limiting its presence in the area.

6. *Acer saccharum* is not present, and *Acer rubrum* is only sparsely represented, although the area presents ideal conditions for the establishment of the latter species.

7. In view of the prevalence and apparent stability of Fagus in the Crawford woods, it seems likely that edaphic modifications (improved drainage and increased soil aeration) will have to occur before the true Acer-Fagus climax can be reached.

ACKNOWLEDGMENT

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TABLE I

Results of twenty-five 100-square meter quadrat study in Crawford Woods.

	Diameter Size Classes										
Species	Below 1 in.	1	2	3-5	6-10	11-15	16-20	Over 20	F. I.	Total Stems Above 1 in.	Total Basal Area in Sq. In.	Approx. Basal Area per Acre in Sq. In.
Acer rubrum	8		1		1			1	24	3	584.226	934.762
Asimina triloba	17								8			
Carpinus caroliniana	4		1						12	1	3.141	5.026
Carya ovata	49						3	1	80	4	1,220.278	1,952.345
Celtis occidentalis	1								4			
Cornus florida	7								8			
Evonymus atropurpureus	23								24			
Fagus grandifolia	171	12	4	2	4	12	45	11	100	78	17,887.193	28,619.509
Fraxinus americana	109	2							60		1.570	2.512
Juniperus virginiana	11	1							40		0.785	1.256
Lindera benzoin	12								12			
Liquidambar styraciflua	97	6	1	3		2	1		76	7	486.854	778.966
Liriodendron tulipifera	8	1	1	1		1			32	3	186.889	299.022
Morus rubra	2								8			
Nyssa sylvatica	92	13	10	10	4	1	1		80	26	713.001	1,140.802
Platanus occidentalis	1								4			
Prunus serotina	4								12			
Quercus alba	11		1						28	1	3.141	5.026
Q. michauxii	1								4			

TABLE I—(Continued)

Results of twenty-five 100-square meter quadrat study in Crawford Woods.

Diameter Size Classes											
Species	Below 1 in.	1	2	3-5	6-10	11-15	16-20	Over 20	F. I.	Total Stems Above 1 in.	Total Basal Area in Sq. In.	Approx. Basal Area per Acre in Sq. In.
Rosa sp.?	3								4			
Sassafras albidum	2				1				12	1	28.269	45.230
Smilax rotundifolia	78								40			
Ulmus americana	3	1	1		1	1			20	3	164.902	263.843

MOLDS ON VEGETABLES IN INDIANAPOLIS RETAIL MARKETS

By Walter A. Miller

Mold growth on market vegetables presents a problem to the storekeeper. Fungi detract from a display of produce and in turn reduce the sale of such produce; and reduction in sales results in loss of the produce. All produce is susceptible to mold growth, some more than others. Studies of molds in local markets have been made by Fisher (1) and Lentz (2). Fisher confined his work to the disease of fruits found in the markets at Evanston, Illinois; and Lentz studied molds on both fruits and vegetables in the Indianapolis markets. Lentz's studies included molds found on produce from the Indianapolis Producers Market and other markets, or wholesale outlets where the produce was offered for sale only to retail markets. Final grading by the commission houses assures the retailer better produce and may also eliminate some of the molds. The molds developing after delivery to the retailer should be fewer. Other factors which may effect the growth of molds are locality of production, weather, temperature, and the difference of seasons and marketing. Lentz (2) studied mold growth on fruits and vegetables during the three month period from September 15, to December 5, 1938. The present study was made from March 1, to May 15, 1948.

METHOD

Inspection of vegetable displays in several retail markets in North Indianapolis were made on Mondays, Wednesdays, and Fridays. Only those vegetables showing evidence of mold growth were collected. The specimens were placed in separate, sterile, deep petri dishes. After the fungus growth had developed fruiting bodies, microscopic examination was made. Identification was made to genus only.

OBSERVATIONS

During the period of March 1 to May 15, seventeen genera of molds were identified from fifty-seven specimens collected (table I). Macrosporium was observed 14 times on 7 different kinds of vegetables: green bean, green pepper, onion, tomato, green pea, egg plant, and beet. Rhizopus occurred 11 times on 5 different kinds of vegetables: cauliflower, turnip, onion, sweet potato, and tomato. Aspergillus was found 4 times on tomato and onion. Periconia was found 3 times on green beans and beets. Monilia, Oospora, Sporodinia, and Fusarium were encountered but twice; and other genera listed in table I were found but once.

Of the vegetables studied, the onion and tomato were hosts to the most kinds of fungi: 7 being identified from onion and 6 from tomato. Turnip and green bean were next with 4 fungi identified from each. The rest of the vegetables listed were hosts to only one or two fungi (table II). Several specimens of lettuce, endive and spinach were collected. These vegetables exhibited disease symptoms; but, in each instance, the disease appeared to be bacterial rot.

DISCUSSION

A comparison between the findings of soil vegetable molds studied by Lentz, and the findings of the present study (table III), shows a difference in genera of fungi encountered. Factors involved in this difference may be due, in part, to the different seasons at which the study was carried on. Lentz's work was done in the fall and early winter. Much of the produce was probably grown locally during the regular growing season. The produce of the present study included hot-house grown vegetables, and vegetables shipped in from other localities. Source of the specimens accounts, to some extent, for the absence of some genera and the presence of others. The molds most prevalent were Macrosporium which occurred in 24.5% of the specimens examined, Rhizopus in 19% and Asperigillus in 7%. Penicillium was found on only 1.7%. Lentz found Rhizopus and Penicillium as chief sources of contamination. This would indicate that the vegetables reaching the retailer are in much better condition because of the weeding-out of contaminated material. Other genera, not found in retail markets but which were found from other sources, include Alternaria, Botrytis, Verticillium, and Isaria. The incidence of Oospora and Fusarium was found to be lower on retail market vegetables.

SUMMARY

1. Seventeen genera of fungi were identified from 57 specimens of vegetables collected in retail markets in North Indianapolis during

the period from March 1, to May 15, 1948.

2. Contaminants most common to all specimens in order found were: Macrosporium, Rhizopus, Aspergillus, and Periconia.

3. Incidence of Penicillium and Rhizopus was much lower in retail markets than in other sources listed by Lentz in a similar study.

4. Vegetables upon which more than two genera were found were tomato, onion, green bean, and turnip.

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TABLE I

Hosts serving a substrates for pathogens.

Pathogen	Host
1. Rhizopus	Cauliflower, Turnip, Onion, Sweet Potato, Tomato
2. Macrosporium	Green Bean, Green Pepper, Onion, Tomato Green Pea, Egg Plant, Beet
3. Monilia	Turnip, Celery
4. Penicillium	Onion
5. Aspergillus	Onion, Tomato
6. Oospora	Turnip, Tomato
7. Phycomyces	Green Bean
8. Sporodinia	Green Bean, Tomato, Onion
9. Periconia	Green Bean, Beet
10. Circinella	Green Pepper
11. Spinellus	Onion
12. Fusarium	Onion, Squash
13. Trichosporium	Green Pea
14. Monosporium	Parsnip
15. Hyalopus	Rhubarb
16. Botryosporium	Turnip
17. Trichothecium	Tomato

TABLE II

Pathogens occurring on each host.

Host	Pathogens
1. Cauliflower	Rhizopus
2. Turnip	Monilia, Oospora, Rhizopus, Botryosporium
3. Celery	Monilia
4. Green Bean	Phycomyces, Macrosporium, Sporodinia, Periconia
5. Green Pepper	Macrosporium, Circinella
6. Onion	Aspergillus, Macrosporium, Spinellus, Rhizopus, Penicillium, Fusarium, Sporodinia
7. Sweet Potato	Rhizopus
8. Tomato	Macrosporium, Trichothecium, Oospora, Rhizopus, Aspergillus, Sporodinia
9. Squash	Fusarium
10. Green Pea	Macrosporium, Trichosporium
11. Parsnip	Monosporium
12. Egg Plant	Macrosporium
13. Beet	Macrosporium, Periconia
14. Rhubarb	Hyalopus

TABLE III

Comparison of Genera of Molds found on Vegetables in the Present Study (March 1-May 15) with those found by Lentz (September 15-December 5).

	Kinds of vegetable on which each genus of mold was found		Percentage of kinds of vegetables on which each genus of mold was found	
Pathogen	Present paper	Lentz	Present paper	Lentz
Macrosporium	7	1	42%	9%
Rhizopus	5	10	30	91
Monilia	2	2	12	18
Penicillium	1	9	6	82
Aspergillus	2	5	12	46
Oospora	2	4	12	36
Phycomyces	1	0	6	0
Sporodinia	2	0	12	0
Periconia	2	0	12	0
Circinella	1	0	6	0
Spinellus	1	0	6	0
Fusarium	2	5	12	46
Trichosporium	1	0	6	0
Monosporium	1	1	6	9
Hyalopus	1	0	6	0
Alternaria		6		55

TABLE III—(Continued)

Comparison of Genera of Molds found on Vegetables in the Present Study (March 1-May 15) with those found by Lentz (September 15-December 5).

	Kinds of vegetable on which each genus of mold was found		Percentage of kinds of vegetables on which each genus of mold was found	
Pathogen	Present paper	Lentz	Present paper	Lentz
Isaria		2		18
Mucor		1		9
Haplaria		1		9
Synsporium		1		9
Monacrosporium		1		9
Sporotrichum		1		9
Acremoniella		1		9
Graphium		1		9
Stemphyllium		1		9
Rhizoctonia		1		9
Trichothecium	1	1	6	9
Verticillium		2		18
Cladosporium		2		18
Botryosporium	1	1	6	9
Stysanus		1		9
Mycogone		1		9
Diplosporium		1		9
Mortierella		1		9
Dendrostibella		1		9
Acrostalagmus		1		9
Colletotrichum		1		9
Total Vegetables	14	11		
Total Mold Genera	17	37		

SOIL REACTIONS OF THE PTERIDOPHYTES OF THE MEGUNTICOOK LAKE REGION NEAR CAMDEN, MAINE[1]

By Jeanne A. Malott

The Megunticook Lake region is an area of approximately five miles square located between Lincolnville on the north and Camden on the south, the Atlantic Coast on the east and extending west beyond the lake to the summit of Ragged Mountain (1300 ft.). Included in this section and surrounding Lake Megunticook are Mt. Megunticook (1380 ft.), Mt. Battie (800 ft.), Bald Mountain (1272 ft.), Maiden's Cliff, a precipice rising sheer from the lake (800 ft.), and Cameron Mountain. Most of the land is a part of the Camden Hills State Park in Knox County, "where the mountains meet the sea," and the remainder is on the north side of the lake, in Waldo County. State Road 137 cuts the central part of the region from southeast to northwest.

METHODS

A study of the ferns and fern allies of the territory was attempted by following the marked hiking trails through the mountains and by examining some of the woods along the lake shore and roads. Ferns were collected on as many sites as possible over the region. The purpose of this survey was a study of the soil reaction of the habitats in which they are found. The soil acidity was determined with a Beckman pH Meter using samples taken from the immediate vicinity of the roots of the plants. The pH readings were compiled and averaged in table I and compared with those from other locations in table II.

LITERATURE REVIEWED

Many contributions have been made on the subject of soil relations and preferences of plants in relation to plant distribution and growth. Research has been done on the acidity of pteridophyte habitats by Craw (1) in Indiana; by Robinove and LaRue (4) in the Douglas Lake Region, Michigan; by Spurway (6), and Wherry (8-14) in the northeastern part of the United States. The last especially has been interested in the importance of the relationship between plants and their soil reactions as an influencing factor in distribution and even as an indicator of evolution (10). Wherry (8, 9) tested the soil habitats of many ferns growing on rocks and in swamps and woods in order to determine the pH range in which they will grow or which they will tolerate. Craw (1) conducted similar experiments with native ferns of Indiana, arriving at nearly the same results and conclusions. Spurway (6) compiled a reference list of plants and their soil reactions as to toleration and optimum and included many of the major pteridophytes. Robinove and LaRue (4) studied pH reactions of soils of Bryophytes and Pteridophytes around Douglas Lake, Michigan. All find the ranges rather wide for individual species with one kind of plant not usually growing equally well under both acid and alkaline conditions. Any evidence of such adaptation, states Wherry, is an indication of a high place in the evolutionary scale (10).

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[1] A portion of a thesis submitted in partial fulfillment of the requirements for the degree Bachelor of Arts, magna cum laude, Butler University.

OBSERVATIONS AND RESULTS

The soil of the region is prevailingly acid to circumneutral, as is indicated by the presence of acid loving plants such as the Bunchberry (*Cornus canadensis*) and numerous ericaceous shrubs and undershrubs. The mountains afford a topography varying from dry barren rocks and hillsides, open or shaded by oak, maple, beech or dense pine stands, to quite moist conditions. Some deep and very shaded ravines are characteristic, where rich humus soil has accumulated and which are often damp or boggy due to springs at the bases of the large rocks. Many places along the flats are also swampy, providing typical marshy environment. Several of the trails follow mountain streams, supplying ideal habitats for many of the northeastern ferns.

The following ferns and fern allies were collected from June 22 to August 7, 1947:

Botrychium dissectum v. *obliquum* (Muhl.) Clute. The Coarse-Lobe Grapefern. Soil very slightly acid to circumneutral (6.25). Rare: found only once.

Botrychium lanceolatum v. *angustisegmentum* Pease and Moore. The Triangle Grapefern. Found in boggy places. Soil slightly acid to circumneutral (6.21-6.32). Rare: found on a swamp hummock.

Botrychium matricariaefolium A. Br. The Daisyleaf Grapefern. Discovered in moist rich places. Soil circumneutral (6.4-6.48). Rare: found only twice.

Botrychium virginianum (L.) Sw. The Rattlesnake Fern. Rich, moist soil. Soil circumneutral (6.22-6.41). Not abundant, but well distributed: the most common grapefern of the region.

Osmunda regalis v. *spectabilis* (Willd.) Gray. The Royal Fern. Found in moist thickets and slopes and boggy places. Soil subacid (6.01-6.38).

Osmunda claytoniana The Interrupted Fern. Frequent everywhere in moist places. Soil subacid to circumneutral (6.08-6.6). Common over the area.

Osmunda cinnamomea The Cinnamon Fern. Soil subacid to circumneutral (6.08-6.66). Quite abundant.

Dennstaedtia punctilobula (Mx.) Moore. The Hayscented Fern. Seen especially along roads, low trails and in pastures. Soil subacid to circumneutral (6.08-6.61). Very common.

Pteridium aquilinum v. *latiusculum* (Desv.) Underw. The Eastern Bracken Fern. Most any soil is favorable up to rather dry. Grows both small and large. Soil circumneutral (6.08-6.48). Common and widespread.

Pteretis pennsylvanica v. *pubescens* (Terry) Fern. The Ostrich Fern. Very graceful and outstanding. Grows on rich, talus slopes and moist flats. Especially large on the Spring Brook Trail. Soil circumneutral (6.31-6.69). Rare.

Onoclea sensibilis L. The Bead-Fern. Abundant everywhere except on high rocky places. Soil circumneutral (6.38-6.69). Well distributed. *Onoclea sensibilis* v. *obtusalobata* was found at Hosmer's Pond.

Woodsia ilvensis (L.) R. Br. The Rusty Cliff-fern. Occurs sparingly on high, rocky places and dry cliffs where it is cool. Soil subacid to circumneutral (6.13-6.22).

Cystopteris fragilis v. *protusa* Weatherby. The Lowland Brittle Fern. Found along moist trails and wooded slopes in rock crevices. Soil circumneutral (6.44). Not common.

Athyrium angustum (Willd.) Presl. The Northern Lady Fern. Abundant along roads and trails in rather moist places. Soil circumneutral (6.39-6.6).

Dryopteris intermedia (Muhl.) Gray. The Evergreen Wood Fern. Found on cool, damp slopes. Soil circumneutral (6.22-6.45). Quite common on shady, rocky places.

Dryopteris spinulosa (Mueller) Watt. The Toothed Wood Fern. Found frequently with *D. intermedia* in moister places. Soil circumneutral (6.3-6.48). Fairly common.

X. *Dryopteris pittsfordense* (*D. spinulosa* x *marginalis*). Soil circumneutral (6.17). Found only once on the Clay Brook Trail.

Dryopteris campyloptera (Kunze) Clarkson. The Mountain Wood Fern. Found in high, moist places in ravine slopes. Soil circumneutral (6.2-6.25).

Dryopteris marginalis (L) Gray. The Marginal Woodfern. Scattered over the area on all the slopes in cool, damp places. Soil circumneutral (6.3-6.16). Abundant.

Dryopteris clintoniana (D. C. Eaton) Dowell. The Broad Swamp Fern. Found very sparsely in boggy or very wet places. Soil circumneutral (6.34). Rare.

Dryopteris cristata (L) Gray. Narrow Swamp Fern. Occurs in wet, low, marsh grounds along streams. Soil circumneutral (6.34-6.4).

Dryopteris bootii (Tucerm) Underw. Glandular Swamp Fern. In cool, damp, swampy places. Soil circumneutral (6.32-6.48). Rare: found only twice.

Dryopteris thelypteris v. *pubescens* (Lawson) Nakai. The Northeastern Marsh Fern. Found mostly in colonies in marshy, low places. Soil circumneutral (6.31-6.6). Abundant but not too well distributed.

Dryopteris noveboracensis (L) Gray. The Tapering Fern. On the trails in cool, shaded places. Soil circumneutral (6.3-6.45). Quite abundant.

Polystichum acrostichoides (Mx.) Schott. The Christmas Fern. On all slopes in damp shaded areas; rock crevices in rich humus. Soil circumneutral (6.33-6.6). Very common. *P. acrostichoides* v. *incisum* was found twice with the others.

Phegopteris polypodioides Fee. The Northern Beech Fern. In moist shady places frequently on rocks. Soil circumneutral (6.22-6.52). Common.

Phegopteris dryopteris (L.) Fee. The Woodland Oak Fern. Found often with the Beech Fern in cool, rocky woods. Soil circumneutral (6.22-6.4).

Polypodium virginianum L. The Rockcap Fern. Abundant on boulders and cliff ledges. Very noticeable. Soil circumneutral (6.21-6.45).

Lycopodium lucidulum Mx. The Shining Clubmoss. Occurs sparsely in decidedly wet places with rich soil. Soil circumneutral (6.46-6.5).

Lycopodium annotinum L. The Bristly Clubmoss. In damp, cool places. Soil subacid (6.0-6.48). More common than the preceding.

Lycopodium clavatum L. The Running Clubmoss. Almost all trails and slopes near the lake. Soil subacid to circumneutral (6.2-6.44). Most common clubmoss.

Lycopodium obscurum L. and *L. o.* v. *dendroideum* (Mx) D. C. Eaton. The Flat Branch Ground Pine and the Round Branch Ground Pine. Found scattered over the area especially in dry woods and open places. The soil of the first is subacid; the second is circumneutral (6.0-6.48). Fairly common.

Lycopodium tristachyum Pursh. The Groundcedar. Rocky, dry open woods. Found only in one place.

Lycopodium flabelliforme (Fern.) Blanch. The Running Pine. Common throughout the area. Soil circumneutral (6.4-6.6).

Equisetum prealtum Raf. American Scouring Rush. Occurring on low ground along the lake. Soil circumneutral (6.31-6.37). Not common.

Equisetum fluviatile L. The Water Horsetail. Found in very moist places such as ditches. Soil circumneutral (6.38). Very rare.

Equisetum sylvaticum L. The Wood Horsetail. Found in cool, damp places and bogs. Soil circumneutral (6.25-6.6). Most common horsetail.

Equisetum arvense L. The Field Horsetail. Not found often but must be present in sandy soils along the lake. Soil circumneutral (6.54).

TABLE I

Soil Reaction (pH) of the Various Sites of the Pteridophytes in the Megunticook Lake Region

	pH	Active Acidity
1. *Botrychium dissectum* v. *obliquum*		
Bog Hummock on the Truck Trail	6.25	5.5
2. *B. lanceolatum*		
Truck Road	6.32	4.8
Spring Brook Trail	6.3	5.0
Tsuga Lodge Woods	6.21	5.9
Average	6.28	5.25
3. *B. matricariaefolium*		
Spring Brook Trail	6.48	3.2
Bog on the Truck Trail	6.4	4.0
Average	6.44	3.6
4. *B. virginianum*		
Spring Brook Trail	6.22	5.8
Maiden's Cliff Trail	6.41	3.9
Average	6.31	4.9
5. *Osmunda regalis* v. *spectabilis*		
Truck Trail	6.01	10.0
Bridge Road	6.18	6.4
Hosmer's Pond	6.38	4.2
Average	6.16	6.8
6. *O. Claytoniana*		
Road 137	6.6	2.0
Mt. Battie	6.48	3.2
Ski Trail	6.43	3.7
Spring Brook Trail	6.08	8.4
Ragged Mountain	6.3	5.0
Clay Brook Trail	6.4	4.0
Average	6.38	4.38
7. *O. cinnamomea*		
Beaucaire Avenue	6.6	2.0
Tsuga Lodge Woods	6.48	3.2
Mt. Battie	6.54	2.6
Maiden's Cliff	6.39	4.1

TABLE I—(Continued)

Soil Reaction (pH) of the Various Sites of the Pteridophytes in the Megunticook Lake Region

	pH	Active Acidity
Lake Woods	6.31	4.9
Spring Brook Trail	6.08	8.4
Average	6.38	4.2
8. *Dennstaedtia punctilobula*		
Tsuga Lodge Woods	6.48	3.2
Maiden's Cliff	6.51	2.9
Mt. Battie	6.38	4.2
Spring Brook Trail	6.08	8.4
Clay Brook Trail	6.4	4.0
Average	6.37	4.5
9. *Pteridium aquilinum* v. *latiusculum*		
Tsuga Lodge Woods	6.48	3.2
Mt. Battie	6.25	5.5
Ski Trail	6.25	5.5
Spring Brook Trail	6.98	8.4
Clay Brook Trail	6.35	4.5
Average	6.28	5.4
10. *Pteretis pennsylvanica* v. *pubescens*		
Tsuga Lodge Woods	6.45	3.5
Ragged Mountain	6.385	4.2
Spring Brook Trail	6.31	4.9
Average	6.38	4.2
11. *Onoclea sensibilis*		
Road 137	6.69	1.55
Mt. Battie	6.55	2.5
Hosmer's Pond	6.38	4.2
Clay Brook Trail	6.6	2.0
Average	6.55	2.56
12. *Woodsia ilvensis*		
Mt. Megunticook Trail	6.13	7.4
Maiden's Cliff	6.22	5.8
Average	6.18	6.6

TABLE I—(Continued)

Soil Reaction (pH) of the Various Sites of the Pteridophytes in the Megunticook Lake Region

	pH	Active Acidity
13. *Cystopteris fragilis* v. *protrusa*		
Tsuga Lodge Woods	6.6	2.0
Maidens Cliff	6.28	5.2
Average	6.44	3.6
14. *Athyrium angustum*		
Beaucaire Avenue	6.6	2.0
Tsuga Lodge Woods	6.48	3.2
Mt. Battie	6.43	3.7
Ski Trail	6.52	2.8
Ragged Mountain	6.39	4.1
Clay Brook Trail	6.4	4.0
Average	6.47	3.3
15. *Dryopteris intermedia*		
Mt. Battie	6.45	3.5
Spring Brook Trail	6.22 6.48	5.8 3.2
Ragged Mountain	6.3	5.0
Clay Brook Trail	6.5	3.0
Tableland Trail	6.43	3.7
Average	6.38	4.03
16. *Dryopteris spinulosa*		
Tsuga Lodge Woods	6.48	3.2
Mt. Battie	6.4	4.0
Spring Brook Trail	6.48	3.2
Ragged Mountain	6.3	5.0
Clay Brook Trail	6.35	4.5
Average	6.4	3.98
17. X *Dryopteris pittsfordensis*		
Clay Brook Trail	6.17	6.8
18. *Dryopteris campyloptera*		
Ski Trail	6.25	5.5
Clay Brook Trail	6.2	6.15
Average	6.22	5.82

TABLE I—(Continued)

Soil Reaction (pH) of the Various Sites of the Pteridophytes in the Megunticook Lake Region

	pH	Active Acidity
19. *Dryopteris marginalis*		
Tsuga Lodge Woods	6.48	3.2
Mt. Battie	6.6	2.0
Maiden's Cliff	6.4	4.0
Spring Brook Trail	6.48	3.2
Ragged Mountain Trail	6.3	5.0
Clay Brook Trail	6.5	3.0
Average	6.49	3.4
20. *Dryopteris clintoniana*		
Bog on Truck Road	6.34	4.6
21. *Dryopteris cristata*		
Tsuga Lodge Woods	6.4	4.0
Truck Road Bog	6.34	4.6
Average	6.39	4.3
22. *Dryopteris bootii*		
Spring Brook Trail	6.48	3.2
Bog on Truck Road	6.32	4.8
Average	6.4	4.0
23. *Dryopteris thelypteris* v. *pubescens*		
Ragged Mountain	6.38	4.2
Hosmer's Pond	6.37	4.3
Clay Brook Trail	6.6	2.0
Road 137 at Youngstown Road	6.31	4.9
Average	6.45	3.8
24. *Dryopteris noveboracensis*		
Road 137 at Youngstown Road	6.31	4.9
Clay Brook Trail	6.4	4.0
Ragged Mountain	6.45	3.5
Spring Brook Trail	6.3	5.0
Maiden's Cliff	6.31	4.9
Tsuga Lodge Road	6.4	4.0
Mt. Battie	6.3	5.1
Average	6.35	4.5

TABLE I—(Continued)

Soil Reaction (pH) of the Various Sites of the Pteridophytes in the Megunticook Lake Region

	pH	Active Acidity
25. *Polystichum acrostichoides*		
Beaucaire Avenue	6.6	2.0
Tsuga Lodge Road	6.48	3.2
Maiden's Cliff	6.45	3.5
Mt. Battie	6.35	4.5
Clay Brook Trail	6.4	4.0
Spring Brook Trail	6.33	4.7
Ragged Mountain	6.43	3.7
Average	6.43	3.6
26. *Phegopteris polypodioides*		
Ski Trail	6.52	2.8
Maiden's Cliff	6.45	3.5
Tsuga Lodge Road	6.4	4.0
Mt. Battie	6.48	3.2
Spring Brook Trail	6.22	5.8
Ragged Mountain	6.4	4.0
Average	6.4	3.9
27. *Phegopteris dryopteris*		
Ski Trail	6.25	5.5
Tsuga Lodge Road	6.4	4.0
Clay Brook Trail	6.22	5.8
Spring Brook Trail	6.22	5.8
Ragged Mountain	6.33	4.7
Average	6.31	4.8
28. *Polypodium virginianum*		
Mt. Battie	6.21	5.9
Ragged Mountain	6.45	3.5
Maiden's Cliff	6.43	3.7
Average	6.36	4.3
29. *Lycopodium lucidulum*		
Clay Brook Trail	6.46	3.4
Mt. Battie	6.48	3.2
Ski Trail	6.5	3.0
Average	6.48	3.2
30. *Lycopodium annotinum*		
Spring Brook Trail	6.3 6.0	5.0 10.1

TABLE I—(Continued)

Soil Reaction (pH) of the Various Sites of the Pteridophytes in the Megunticook Lake Region

	pH	Active Acidity
Mt. Battie	6.48	3.2
Truck Road	6.32	4.8
Average	6.27	5.0
31 *Lycopodium clavatum*		
Bog on Truck Road	6.25	5.6
Clay Brook Trail	6.44 6.22	3.6 6.0
Truck Road	6.32	4.8
Average	6.3	5.0
32. *Lycopodium obscurum*		
Spring Brook Trail	6.3 6.0	5.0 10.1
Swamp on Ski Trail	6.25	5.5
Mt. Battie	6.48	3.2
Truck Road Bog	6.32	4.8
Clay Brook Trail	6.45	3.5
Average	6.44	3.6
33. *Lycopodium flabelliforme*		
Beaucaire Avenue	6.6	2.0
Mt. Battie	6.48	3.2
Tsuga Lodge Road	6.4	4.0
Average	6.49	3.1
34. *Equisetum prealtum*		
Woods on Road 137	6.31	4.9
New Road	6.37	4.3
Average	6.34	4.6
35. *Equisetum fluviatile*		
Ragged Mountain	6.38	4.2
36. *Equisetum sylvaticum*		
Mt. Battie	6.48 6.55	3.2 2.5
Beaucaire Avenue	6.6	2.0
Bog on Truck Road	6.25	5.5
Average	6.47	3.3
37. *Equisetum arvense*		
Ski Trail	6.54	2.6

TABLE II

A Comparison of the Soil Reaction of the Ferns in Maine with the Same Species Found in Indiana and Other Locations.

	Soil Reaction Range								
		Maine		Indiana		Michigan Douglas Lake		Northeast	
Species	No. of Tests	Present Study 1947	No. of Tests	1932 (1)	No. of Tests	1928 (4)	No. of Tests	1920-21 (9)	General Collection 1941 (6)
Botrychium obliquum	1	6.25	12	5.5-6.5				Circumneu.	
Botrychium virginianum	2	6.22-6.41	92	5.5-8.0	9	5.2-8.0		Circumneu.	
Osmunda regalis v. spectabilis	3	6.01-6.38	33	4.5-6.5	8	4.2-5.8	30	4.5-6.5	4.0-6.0
O. claytoniana	6	6.08-6.6	17	5.5-7.0	5	4.2-5.8	20	4.5-7.5	5.7
O. cinnamomea	6	6.08-6.6	27	4.5-7.0	5	4.2-5.8	30	4.5-6.5	4.5-5.5
Dennstaedtia punctilobula	6	6.08-6.51						4.5-8.0	4.7
Pteridium aquilinum v. latiusculum	5	6.08-6.48			3	4.6-6.8	30	4.5-6.5	
Pteretis pennsylvanica v. pubescens	3	6.31-6.45	6	6.5-7.5	1	7.3	20	6.0-8.5	6.5-7.5
Onoclea sensibilis	4	6.38-6.6	65	4.5-7.5	8	4.8-8.0	30	4.5-8.0	5.5-7.5
Woodsia ilvensis	2	6.13-6.22					25	5.0-6.5	5 -6
Cystopteris fragilis	2	6.28-6.6	73	5.0-8.5			30	5.0-8.5	6 -8
Athyrium angustum	6	6.39-6.6					10	5.5-8.0	6 -7
Dryopteris intermedia	6	6.22-6.48			8	4.8-6.4	20	4.5-8.0	6.7
Dryopteris spinulosa	5	6.3 -6.48	36	4.0-6.5	8	4.2-6.4	20	4.5-8.0	4.5-6
Dryopteris campyloptera	2	6.2 -6.25*					3	6.0	
Dryopteris marginalis	6	6.3 -6.6	13	5.0-7.0			30	5.0-8.0	5 -8.5
Dryopteris clintoniana	1	6.34					2	6.0-7.5	
Dryopteris cristata	2	6.34-6.4	24	4.5-7.0	4	6.0-6.6	20	4.5-8.0	4.5-8

TABLE II—(Continued)

A Comparison of the Soil Reaction of the Ferns in Maine with the Same Species Found in Indiana and Other Locations.

	Soil Reaction Range								
		Maine		Indiana		Michigan Douglas Lake		Northeast	
Species	No. of Tests	Present Study 1947	No. of Tests	1932 (1)	No. of Tests	1928 (4)	No. of Tests	1920-21 (9)	General Collection 1941 (6)
Dryopteris bootii	2	6.32-6.48					20	4.5-8.0	4.5-8
Dryopteris thelypteris v. pubescens	4	6.31-6.6	45	4.5-8.0	9	4.8-8.2	30	4.5-8.0	4 -6
Dryopteris noveboracensis	7	6.3 -6.45	29	4.5-7.0	8	4.2-6.4	30	4.5-8.0	4 -7
Polystichum acrostichoides	6	6.33-6.6	91	5.0-8.5			30	4.5-8.0	6 -8
Phegopteris polypodioides	6	6.22-6.52					20	4.5-8.0	4.5-8
Phegopteris dryopteris	5	6.22-6.4			3	6.0-7.6	30	4.5-7.5	5 -7.5
Polypodium virginianum	3	6.21-6.45	10	4.5-6.0			50	5.0-8.5	5 -8
Lycopodium lucidulum	3	6.46-6.5*			1	6.6		Acid	
Lycopodium annotinum	3	6.0 -6.48*			4	5.8-6.2		Subacid	4.5-5
Lycopodium clavatum	3	6.2 -6.4			6	5.5-6.4		Suba.-cir.	
Lycopodium obscurum	5	6.0 -6.48*			3	6.2-6.5		Circumneu.	
Equisetum prealtum	2	6.31-6.37*			1	7.4		Circumneu.	
Equisetum fluviatile	1	6.38*			2	5.6-5.8		Suba.-cir.	4.5-6
Equisetum sylvaticum	3	6.25-6.6			5	5.2-8.2		Circumneu.	
Equisetum arvense	1	6.54*			9	6.4-7.8		Circumneu.	4.5-6

Mediacid—4.5-5.0 Subacid—5.5-6.0 Acid—6.0-6.5 Circumneutral—6.5-8.0

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* These represent the places where the author's figures are not contained within the limits found by the other authors.

DISCUSSION

There has been an increasing emphasis placed recently on the relationship of soil habitats to the distribution and growth of plants. Christopherson (11) concludes that "each plant association of the area (Sylene National Park, Norway) is limited in its distribution to soils within a definite and relatively narrow range of reaction." Studies of pH ranges in which pteridophytes will exist, for example, have provided many relevant reasons why unusual habitats were found in so many cases for ferns arbitrarily determined as "alkaline" or "acid" loving (13). Wherry (12) found soil reactions to be a very important controlling factor in plant distribution. The present study, done on the pteridophytes of the region around Lake Megunticook in Maine, while not based on as large a number of samples as similar earlier work, has agreed quite well with the results obtained by Wherry with northeastern ferns (9), Craw in Indiana (1), and Robinove and LaRue in Michigan (4). A comparison of the results may be found in table II.

The most striking difference between the results of the present study and those of earlier workers is the narrower pH range in the present study for most of the species. It is not possible to determine to what extent this narrower range is real and to what extent it is due to smaller number of sites used and to selection of more luxuriant specimens.

The pteridophytes seem to stay within "acid" or "circumneutral" limits, showing preference for one or the other (table I) and sometimes a tolerance even for an atypical habitat. Those with the largest number of determinations were in all cases too few to draw definite conclusions about the range limits, but it can be observed that the ranges remain, with a few exceptions, within the limits found by other workers. The present results tend to substantiate Wherry's theory that northern ferns prefer less acid habitats (12). Also all the tests made indicate that neither a high soil acidity nor an excessive alkalinity is present anywhere in the region. It seems to be true that ferns closely related, such as those of the genus Dryopteris, prefer similar habitats; the Dryopteris species have soils ranging in pH from 6.2 to 6.6. The representative Osmunda species show this same similarity with a range from 6.01 to 6.6. The lycopods and Equisetineae of the region have as wide a range of habitat as the other genera and are distributed rather widely, although the latter were less general and usually in a more acid habitat.

It was noticed in the collection of ferns that all chosen for specimens were growing luxuriantly and were strong both as stands and as individuals. Perhaps this would help to account for the narrow reaction ranges exhibited by the soil samples examined. It has been observed previously (6) that an excessive alkalinity or acidity in the substrata would be likely to produce stunted growth. Therefore, it seems probable that these pH values represent more nearly optimum conditions, in which the pteridophytes would obviously show the most prolific development.

SUMMARY AND CONCLUSIONS

1. Thirty-eight different species of pteridophytes were collected in this survey of the Lake Megunticook region in Maine. Soil samples were collected from as many sites as possible to determine the soil reactions in an attempt to determine whether there is any relationship between habitat and distribution.

2. The pH limits found in this study are 6.0-6.6. It may be observed that these extremes are not radically different from any one of the individual ranges for each species.

3. The range in this study is, with a few exceptions, definitely narrower but within Wherry's range for the same species. In the case of *Osmunda cinnamomea,* the range was little higher for the upper limit. But in every instance, the lower limit was higher than his lower limit. It seems that soils generally occupied by ferns in this study were less acid than those examined by Wherry.

4. These ranges are also within the limits of those found by Craw (1), Robinove and LaRue (4), and Spurway (6), with only 7 exceptions and in all such cases the number of tests is very low. Of these only two (*Lycopodium lucidulum* and *Equisetum prealtum*) show a tolerance of slightly greater acidity; the remainder show the soils in the present study to be less acid than those found by the other workers.

5. The results from the present study are in agreement with Wherry's conclusion that northern ferns tend to prefer more nearly alkaline habitats.

6. The fact that the pH ranges in this study are decidedly narrower than those found by Craw (1) or Wherry (7-11) is probably partly due to the smaller number of soil samples taken and partly to the fact that the territory under survey was much smaller. Craw (1), for example, worked over the entire state of Indiana, while the region in Maine was only five miles square. Also, the total number of samples taken in Maine was 123 while Craw collected 560 for a somewhat smaller number of species. Wherry used 530 samples from all over the northeast. The results, then, are what might be expected for a considerably smaller area of research. If a larger number of determinations had been made, a greater range would possibly have been secured.

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A STUDY IN SOIL MOISTURE, ACIDITY AND EVAPORATION IN AN UPLAND WOODS AT TURKEY RUN STATE PARK[1]

By MARY FRITSCHE CUNDIFF

Structure and development of vegetation has reflected the biological value of the habitat, for vegetation responds to changes in habitat readily; and habitat, in turn, is determined, in its gross characteristics, by climate. However, a uniform climate does not exist even in a small geographical area because the area is modified by peculiar features of soil and physiography. The variety of habitats, e.g., in dissected land surfaces, is in direct proportion to these modifications of the macroclimate. Such features, while perhaps not affecting the arboreal cover, will determine different accents of the secondary and herbaceous layers as pointed out by Friesner and Potzger (5).

Most of Indiana has been placed in the deciduous forest climax (12). However, the associations of the deciduous forest formation have aroused a great deal of debate in classification. Beech-maple and oak-hickory associations were discussed by early writers, but Potzger (12) pointed out in 1935 that in Indiana beech-maple is a mixed mesophytic type with beech-maple tendencies. According to Braun (1), who has most recently classified forest types, Indiana is a part of the western mesophytic forest. But under extreme conditions even forest cover may be controlled by microclimatic variations as described by Friesner and Potzger (6, 12). And so, microclimatic areas in Indiana, those areas in which physiographic features are extreme, will markedly alter the forest type; species out of normal range will associate or compete with the typical species of the mixed mesophytic forest. Turkey Run State Park is such an area, for relic colonies of eastern hemlock persist even now under rather static conditions.

This study in soil moisture, acidity and evaporation was initiated in an attempt to measure some of the differences which must contribute to the unusual vegetative makeup of the forest. Daubenmire (4) and Esten (8) have made previous ecological studies of the park.

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[1] A portion of a thesis submitted in partial fulfillment of the requirements for the degree Bachelor of Arts, magna cum laude, Butler University.

LOCATION AND HISTORY OF THE AREA

Turkey Run State Park is located approximately seventy miles west of Indianapolis in the northeast central part of Parke county. While cutting has occurred in part of the present park area, the area of the forest selected for this study has apparently never been lumbered or burned over, for no cut stumps or charred remains were visible. Since it is the policy of the state park system to leave the woods undisturbed, it may be assumed that since 1916 (when the state acquired the property) no man-introduced activity has been present. These two facts indicate then that the forest stand may be primeval; at any rate, it has developed without disturbance for more than thirty years.

PHYSIOGRAPHIC FEATURES

This park lies in a part of the Tipton till plain where considerable relief exists. Sugar Creek which divides the park, is entrenched in the Mansfield sandstone (Pennsylvanian); and the tributaries which run into Sugar Creek as well as the ravine drainage system dissect the upland plain. Since it is postulated (2) that out-going glacial waters partially excavated Sugar Creek and its tributaries, glacial drift then was the strata upon which the present vegetation was established. The surface deposit of the drift is composed principally of red clay, sand and gravel and "the red clay often gives place to a dark carbonized soil (2)." According to the geological survey (2), deposits showed an interstratification which indicated deposition with no ordered superposition.

METHODS

Five stations were established for atmometer study because of differences either in the herbaceous flora or in the tree cover. Soil samples at the surface, 6- and 12-inch levels were collected weekly at each of the five stations; acidity determinations were made from these samples. Eighteen 100-sqm. quadrats were taken in the forest to indicate composition.

Two Livingston atmometers equipped with rain valves were placed approximately thirty centimeters above the surface of the ground in each of the five stations. The atmometers were filled with distilled water every Monday morning between June 23, 1947, and September 1, 1947. At station A, the atmometers were placed near the top of a small dip on the north side of the rather shallow ravine which dropped to the floodplain level. At station C, the instruments were on a gentle, open northwestern slope. At the remaining three stations, the instruments were placed in the midst of the growth peculiar to that particular area. The readings from each two atmometers were averaged to determine the loss at each station.

At each of the five stations (within a 15-foot radius) soil samples were taken on the surface, at 6-inch and at 12-inch depths. The soil samples were placed into tin soil cans which were sealed with tape and mailed to Butler University. In the botanical laboratory they were weighed in and then placed into an incubator for at least 48 hours at a temperature of 100° C. After this period of drying they were reweighed and the percentage of moisture in relation to dry weight was calculated.

Readings of soil acidity were made on the Beckman pH meter. Three readings were made on samples for each three levels of the five stations. The readings were converted into active acidity, averaged, and reconverted to pH (table III). Moisture equivalents of the levels of the five stations were determined and wilting coefficients established according to the formula found in Weaver and Clements (13).

The line of quadrats was begun in the leatherwood type forest, and the quadrats were laid in an area separating the hemlock stand from the leatherwood type of mixed mesophytic forest. Each 100-sqm. quadrat was followed by a skip of a similar quadrat.

The results of the quantitative data gathered are shown in tables I-IV and figures 1-6.

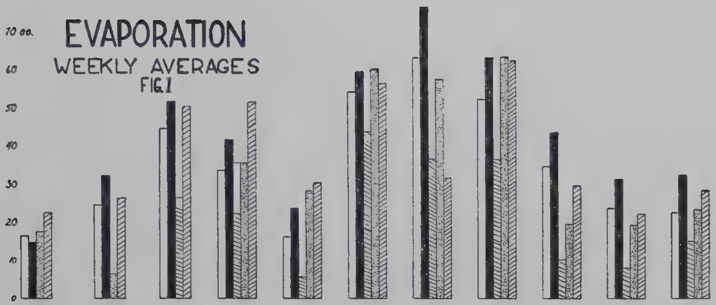
DESCRIPTION OF STATIONS

The hemlocks (station A) were found growing on a northerly slope of a ravine that was at about right angles to the east-west flow of Sugar Creek. The diameter and height of the hemlocks decreased as the wedge of evergreens at the creek narrowed as it reached into the upland. The ground under the hemlocks was completely covered with leaves under which a great deal of decaying organic matter was

EVAPORATION

WEEKLY AVERAGES

FIG.I



PERCENTAGES OF SOIL MOISTURE

FIG.2 SURFACE

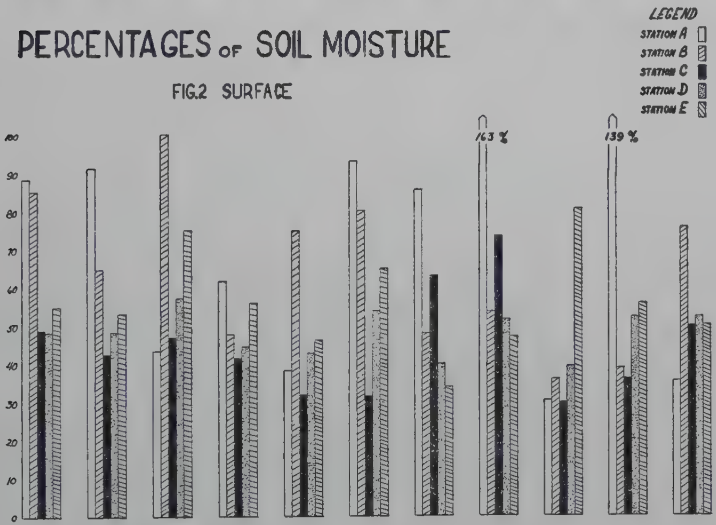


FIG.3 SIX INCHES

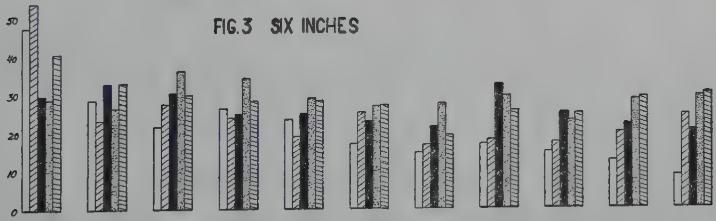
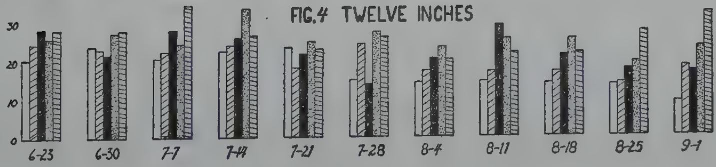


FIG.4 TWELVE INCHES



found. The "surface" of the soil appeared to be composed of partially to nearly decayed leaves. At about 6 inches, however, the soil changed from this brownish-black decayed material to a yellowish clay.

The stand of young beech (station B, in which most of the trees were 1-3 inches DBH.) was east and a little north of the relic hemlock colony (station A) and extended to a trail (Trail 5) which ascended from the floodplain through the eastern part of the hemlocks. Here, too, considerable leaf litter was found. In this area the beech separated the hemlocks from the mixed mesophytic woods.

That part of the woods which has been called the mixed mesophytic forest was northwest of the young beech. Three aspects based upon differences in shrub or herbaceous layers were noted. In the first aspect (station A) tall tulip poplar, maple and beech were found with a low herbaceous covering. A few dogwoods were observed, but a secondary tree layer was conspicuously absent. The second aspect (station D) contained a secondary layer of leatherwood, (*Dirca palustris*). The third aspect of the mesophytic woods (station E) contained a secondary layer of jewelweed (*Impatiens pallida*). Stations D and E were 25 yards apart, separated by an extremely shallow ravine. Casual observations indicated striking differences in these areas, the crown cover of which appeared identical.

RESULTS

Evaporation

When weekly averages for the summer were determined, the loss in the atmometers was as follows: beech (station B), 42.9cc.; mixed mesophytic (station C), 38.20cc.; hemlock (station A), 35.44cc.; leatherwood (station D), 32.17cc.; and jewelweed (station E), 23.94cc. Weekly losses are recorded in table I.

Soil Moisture

In all stations the moisture at the surface considerably exceeded that at the lower two levels. Generally the moisture content at the 6-inch level was greater than that at the 12-inch level. The greatest fluctuation in moisture content occurred in the hemlock in the surface level; the moisture content reached as high as 60% above that from any other station and dropped to within 1% of the lowest surface reading for the summer. At both 6- and 12-inch levels, there was in the hemlock a general decrease in the percentage of moisture retained by the soil throughout the entire summer. At the 12-inch level a marked tendency in decrease was found also in the beech. With this one exception, however, the other four stations at the lower two levels showed a limited fluctuation with no tendency to increase or decrease during the period of the study. In the week beginning July 28, the moisture percentage at the 6- and 12-inch levels in the hemlocks dropped to within 10% of the wilting coefficient where it remained until the last week of the study when the readings of both levels were lower than the wilting coefficients. This occurred at no other station. It might be noted also that during the last five weeks of the study the highest two readings in the surface level were recorded. At the surface the percentage of moisture in the hemlocks dropped to within 15% of the wilting coefficient while at the other four stations the percentage of moisture at the surface ranged from 25% to 50% above the wilting coefficient.

Acidity

The pH of the soils showed little difference in the stations of the mixed mesophytic woods at any of the levels although the lower two levels tended to be slightly more acidic (table II). Only in the hemlocks (station A) did distinct differences from the other stations (C, D, E) appear while two readings in the beech (station B) were in the pH range of 5.0.

Quadrat Study

Acer saccharum occurred most frequently in the 18 quadrats with *Fagus grandifolia* the second most abundant species. These numbers, large in comparison with the totals of other species, depended principally upon the trees found in the first three size classes. In the size classes above 6 inches Acer and Fagus have the same number of large trees (table III). *Nyssa sylvatica, Liriodendron tulipifera* and *Fraxinus americana* are other large tree species associated with Acer and Fagus. Acer seedlings are highest in abundance, then Nyssa, Fagus, *Ulmus fulva* and Fraxinus follow in order of decreasing abundance.

DISCUSSION

A. Evaporation

The lowest weekly evaporation rates occurred in the jewelweed station (station E: average, 23.94cc.) and the leatherwood station (station D: average, 32.17cc.) (table I). This might have been expected since these two species are usually limited to habitats with higher ratio of available water to evaporation loss. Next in order of increasing average weekly water loss was the hemlock station (station A) with an average weekly evaporation rate of 35.447cc. This was followed by the mixed mesophytic station (station C: average, 38.177cc.), with the beech station (station B: average, 42.90cc.) showing the highest average weekly evaporation rate. The mixed mesophytic station (station C) thus shows an average weekly loss of 2.73cc. higher than that of the hemlock station (station A). This higher rate of evaporation in the mixed mesophytic station (station C) than in the hemlock station (station A) may be accounted for in part, at least, by the fact that the atmometers in the mixed mesophytic station were completely in the open, the conspicuous absence of anything but a low herbaceous covering having been noted. The atmometers at hemlock station (station A) were a little protected by the dip in which they were situated. Moore *et al.* (10) found that the absence of herbaceous and shrub layers contributed partially to increase in evaporation in hemlock stations. Absence of all except lower herbaceous cover in station C along with the tendency for the lower dead branches of the hemlock at station A to retard air currents perhaps compensated for the higher rate of loss in the mixed mesophytic station.

Daubenmire (4) concluded that the hardwood and hemlock associations were equally mesophytic in respect to evaporation, for he found that an average weekly difference of only .26cc. existed at Turkey Run between these two associations. In contrast, Friesner and Potzger (8) found that hemlock was to be found under conditions somewhat more rigorous than those in mixed mesophytic habitats. As compared to the other two stations in the mixed mesophytic forest in this study (i.e., stations D and E), very considerable differences occurred in the weekly averages between the hemlock (station A) and the jewelweed (station E); while the difference between leatherwood (station D) and the hemlock (station A) was small.

While it should be noted (table I) that the highest average weekly evaporation rate in the present study occurred in the stand of young beech (station B) where the stems were prevailingly 1-3 inches DBH., it should also be noted that the average weekly loss of 42.9cc. was still below the averages for other Indiana stations in previous published reports: Turkey Run: 50.4 cc. (4); Sycamore Creek: 46.2 cc. and 56.7 cc. (9); Brown county: 80.9 cc. (7); and 71.08 cc. (9); and Bartholomew county: 80.45 cc. (9).

SOIL MOISTURE

In the surface layers the hemlock, particularly, showed a singularly high average weekly percentage of moisture. The surface layer under the hemlock (station A) held a high percentage of organic matter and thus had a higher water-holding capacity than those soils with a lower humus content. The surface layer in station B (young beech) was somewhat similar to that of station A and showed the next highest average water content. The great fluctuations of stations A and B were due to the imbibitional qualities of humus. These stations likewise showed the highest wilting coefficients (table I). The high humus content may also account for the universally lower moisture content of the 6- and 12-inch levels. At no time did the moisture content of the surface layer fall below that of the subsurface layers.

To what extent this was due to retention of precipitation preventing it from reaching lower levels, and to what extent it was due to capillary water rising through the subsurface layers, to accumulate in the surface layer in greater percentages than in the subsurface layers, due to greater holding capacity of the humus, is not determinable from the data at hand. Of course, the lower specific gravity of the humus would give higher percentages of moisture in the humus than in the more mineral subsurface layers, even if the total moisture were the same per volume of soils. Daubenmire (4) found the surface layers invariably having higher percentage of total moisture than the subsurface layers in both hardwood and hemlock areas. Friesner and Potzger (7), studying the moisture relations of surface soils of hemlock-seedling sites, found that surface soils with abundant leaf letter almost invariably, during both moist and drought conditions (i.e., both when abundant growth water was available and when there was entire absence of growth water), was higher than where leaf litter was absent.

The summer of 1947 received good rainfall, for only once (week ending September 1) does the moisture percentage fall below the wilting coefficient and then only under hemlock (station A) and at the 6- and 12-inch levels. Beginning in the latter part of July the percentage of growth water available to the hemlocks hovered within 10% of the wilting coefficient for the remainder of the summer. This is in striking contrast to the results of Daubenmire (4) at Turkey Run. During the summer of 1929 he found that under hemlock at the three levels at which soil samples for this present study were taken, there were five, six and seven weeks, respectively when growth water was not available; yet the percentage of moisture in the hardwood never dropped below the wilting coefficient. In August 1947, the weather report at the Rockville station showed that 5:30 inches of rain had fallen in Parke county whereas Daubenmire's graph (4) for August 1929, shows less than two inches of rainfall. It is possible, therefore, that had the summer been drier, in six of the eleven weeks of the study sufficient water for growth would not have been available in the hemlocks and also that a corresponding decrease in rainfall would not have lowered the moisture percentages below the wilting coefficients at the other stations.

ACIDITY

Soil reaction data are given in table I. Other studies (4, 7, 8) indicate consistently a more acid condition in soils of hemlock stations than that which was found at Turkey Run in this study; nevertheless, the reaction in the hemlock station was decidedly more acid than in the stations with deciduous trees. The acidity at station B (young beech) was higher than in the other mixed mesophytic sta-ttions, except in the 6-inch level. This may be related to the fact that this station also showed a higher humus content in the surface layer than was shown by the other mixed mesophytic stations.

QUADRAT STUDY

The quadrat study yielded results in agreement with Braun's recent inclusion of Indiana in the mixed mesophytic type forest (1), for beech and maple were found associated with many other species.

Acer saccharum displayed prolific reproduction, as it does everywhere in Indiana. But since, among the older trees, beech and maple were nearly equally represented, it must be assumed that the mortality of maple is much higher than that of beech. Beech being the ultimate dominant (13), fewer beech seedlings would need to establish themselves in order to survive because beech requires the lesser amount of light.

Friesner and Potzger (8) have pointed out that the hemlock habitat is more rigorous than that of the beech-maple and that during the summer the total soil moisture falls below the wilting coefficient more frequently in hemlock associations than in the beech-maple. It has already been suggested that the rainfall at Turkey Run during the summer of 1947 was too high for deficiency of growth water to occur. That the lower moisture content may be due to the hemlock seems not to be significant since even more rigorous conditions were found where seedlings are growing, before environment can be effected by mature hemlock trees. The members of the mixed mesophytic association do not appear to encroach upon the hemlocks. What factors prevent this does not seem apparent from this study. Available light may be the controlling factor. The hemlocks likewise do not advance into a mixed mesophytic association probably because the depth of leaf litter prevents seedling establishment. Usually, therefore, the line of demarcation between hemlock and hardwoods is static. But there were seedling hemlocks at Turkey Run in the mixed mesophytic area. The wedge of advance into the mixed mesophytic upland followed a ravine upon the sides of which, under more rigorous conditions grew the young hemlocks. Should the ravine be cut further into the upland or widened through erosion, it is likely that these hemlocks may reproduce beyond their present range. There the advancement would not be an aggressive one but rather one due to their ability to take advantage of physiographical developments. But it is safe, perhaps, to say that for the present time the hemlocks have nearly reached their limits in this part of the park, for they have almost reached the head of the present ravine.

The wilting coefficients (table I) of stations A (hemlock) and B (young beech) are very similar and considerably different from the other three stations which in turn show considerable similarity to each other. At the surface layer the wilting coefficients of stations A and

B (22.33 and 20.97 respectively) are much higher than those of the other stations; this being correlated with higher humus content in stations A and B. Conversely, at the 6- and 12-inch levels, the wilting coefficients of stations C, D, and E were quite similar and considerably higher than those for stations A and B.

It is thus apparent that stations A (hemlock) and B (young beech) have considerable similarity between themselves and considerable difference from the mixed mesophytic stations (C, D, and E) in moisture content, wilting coefficient and soil reaction so as to give them distinct microclimatic conditions which in turn are reflected in floristic differences.

When moisture content of the various soils is considered in relation to wilting coefficients it is found that the growth water (table I) shows the highest average for the season in the surface soils of station A but this same station shows the lowest averages for the 6- and 12-inch soils.

SUMMARY AND CONCLUSIONS

1. This study was initiated in an attempt to discover what microclimatic differences may pertain within the different aspects of the mixed mesophytic forest and between them and a relic hemlock colony. The investigation was conducted weekly from June 23, until September 1, 1947.
2. The three aspects of the mixed mesophytic forest, were differentiated by evaporation, soil moisture and growth water differences, evaporation being lowest and growth water highest in the jewelweed station and evaporation being highest and growth water lowest in the open mixed mesophytic while the leatherwood station was intermediate.
3. Hemlock showed a higher soil acidity at all levels and a lower growth water at all levels except the surface, than any of the other stations.
4. Even with abundant rainfall, soil moisture relationships indicated a drier, more rigorous habitat in the hemlocks.
5. Because of the high humus content stations A and B showed a much higher moisture content at surface levels than in all other stations.

6. In all cases moisture content and growth water were higher in surface than in subsurface soils.

7. Moisture content and growth water at the 6-inch level exceeded that at the 12-inch level.

8. The hemlock and young beech stations showed considerable similarity between themselves and considerable differences from the mixed mesophytic stations in moisture content, wilting coefficient and soil reaction.

The writer wishes to express appreciation to Dr. John Potzger for his suggestion of the problem and for his inspection of the set-up of this study; and to Dr. Ray Friesner for his critical reading of the manuscript; to Jack Secor, who weighed and dried the soils in Indianapolis all during the summer; to Gayther Plummer, who collected the soil samples and made the atmometer readings during the month of August; and to Russell Wools and Robert Harmon, who assisted in making the quadrat survey.

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TABLE I

Evaporation, Soil Moisture, Wilting Coefficients, Growth Water, and Soil Acidity.

(Station A, hemlock; station B, beech; station C, mixed mesophytic; station D, leatherwood; station E, jewelweed.)

Week Ending	Station	Average Evaporation	Soil Moisture		
			Surface	6-Inch	12-Inch
6-23	A	16.878	89.41%	47.13%	20.56%
	B	14.99	84.92	43.43	24.76
	C	27.675	49.19	29.48	28.35
	D	17.86	48.74	28.63	26.20
	E		55.19	41.16	28.94
6-30	A	24.766	91.10	28.28	23.41
	B	32.68	64.96	23.09	23.51
	C	26.515	42.82	33.13	21.72
	D	6.84	48.98	26.36	27.72
	E		53.69	33.08	27.82
7-7	A	43.828	43.34	21.40	20.73
	B	51.58	101.33	27.97	22.78
	C	50.765	46.69	30.60	28.16
	D		55.75	36.10	24.81
	E	26.98	75.40	30.05	39.75
7-14	A	33.717	62.06	26.56	22.30
	B	41.86	48.19	23.54	24.10
	C	51.51	41.70	25.16	25.17
	D	35.405	44.81	34.19	33.88
	E	22.8*	56.30	28.55	26.71
7-21	A	16.187	38.26	23.52	23.22
	B	23.56	75.35	19.04	18.06
	C	30.02	36.89	25.25	21.41
	D	18.24*	42.61	29.15	24.77
	E	9.12*	46.60	28.24	22.60

TABLE I—(Continued)

Evaporation, Soil Moisture, Wilting Coefficients, Growth Water, and Soil Acidity.

(Station A, hemlock; station B, beech; station C, mixed mesophytic; station D, leatherwood; station E, jewelweed.)

Week Ending	Station	Average Evaporation	Soil Moisture		
			Surface	6-Inch	12-Inch
7-28	A	54.484	93.30	16.17	14.75
	B	59.14	81.35	25.71	24.59
	C	56.88	41.69	23.22	23.55
	D	60.41	54.10	26.40	27.26
	E	43.74*	65.90	27.34	26.16
8-4	A	63.249	86.27	14.34	14.08
	B	76.31	48.14	16.99	17.44
	C	31.89	63.58	20.97	20.81
	D	57.76	40.28	27.58	23.97
	E	36.63*	34.72	19.18	19.84
8-11	A	52.86	163.95	16.82	14.35
	B	63.85	54.36	17.94	16.76
	C	61.92*	74.32	32.42	29.08
	D	63.65	52.16	31.45	25.89
	E	42.56	47.56	25.68	22.31
8-18	A	35.426	30.74	14.64	13.96
	B	44.06	36.02	17.88	17.06
	C	29.91	29.03	18.66	17.07
	D	19.76	39.09	23.35	25.77
	E	10.26	81.22	24.81	22.25
8-25	A	23.876	139.22	12.87	13.33
	B	31.12	39.26	20.14	14.05
	C	24.385	36.05	21.27	18.85
	D	19.0	52.60	28.30	19.54
	E	8.36	56.14	29.38	27.75
9-1	A	24.65	35.78	8.76	9.91
	B	32.80	76.30	24.56	13.36
	C	28.81	50.12	21.09	16.12
	D	23.845	52.52	29.69	23.40
	E	15.01	50.02	27.30	30.59
Weekly Averages	A	35.447	79.39	20.95	17.32
	B	42.90	63.93	24.73	19.76
	C	38.207	47.46	25.56	22.74
	D	32.177	48.33	29.29	25.746
	E	23.94	56.61	28.60	26.79

TABLE I—(Continued)

Evaporation, Soil Moisture, Wilting Coefficients, Growth Water, and Soil Acidity.

(Station A, hemlock; station B, beech; station C, mixed mesophytic; station D, leatherwood; station E, jewelweed.)

Week Ending	Station	Average Evaporation	Soil Moisture		
			Surface	6-Inch	12-Inch
Wilting Coefficients	A		22.33	10.42	11.08
	B		20.97	11.60	11.10
	C		16.06	14.49	12.48
	D		16.08	13.13	13.27
	E		15.84	14.97	13.73
			Soil Reaction		
Soil Reaction	A		5.0	5.4	5.2
	B		5.9	6.4	5.8
	C		6.6	6.4	6.4
	D		6.4	6.2	6.3
	E		6.4	6.2	6.3
			Growth Water (Average)		
Growth Water (Average)	A		57.06	10.53	6.24
	B		42.96	13.13	8.66
	C		31.40	11.07	10.26
	D		32.25	16.16	12.47
	E		40.77	13.63	13.06

TABLE II

Species of the Eighteen Quadrats in Size Classes.

Species	Below 1"	1	2-5	6-10	11-15	16-20	Above 20	Total stems
Acer saccharum	172	32	50	5	1	1	1	259
A. rubrum	17							17
Carya cordiformis		1					1	2
C. ovata	1					1		2
Cornus florida	11	7	4					22

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* Reading from a single atmometer.

TABLE II—(Continued)

Species of the Eighteen Quadrats in Size Classes.

Species	Below 1"	1	2-5	6-10	11-15	16-20	Above 20	Total stems
Dirca palustris	65							65
Fagus grandifolia	30	24	30	1	2	3	2	92
Fraxinus americana	22		2	1		2		27
Liana species	1							1
Liriodendron tulipifera	2		1			1	3	7
Nyssa sylvatica	35	8	12	1			1	57
Ostrya virginiana	3							3
Prunus serotina	2							2
Quercus alba			1					1
Sassafras albidum	2		1	1	1			5
Smilax sp.	7							7
Ulmus americana	7	1		1				9
U. fulva	30	2	3					35
Viburnum sp.	12							12

TWO NEW ENTITIES IN THE GENUS SOLIDAGO

By RAY C. FRIESNER

Study during the past year of material belonging to this genus from numerous localities has revealed material from two collections which should be described as new entities.

SOLIDAGO LEPIDA var. FALLAX forma *glandulosa* f. nov., caulibus erectis, cylindris, glaberibus vel sparse pubescentibus infra, dense pubescentibus supra, viridis vel stramineis, 1.5 m. altis; foliis basilaris absens; foliis caulinis inferioribus oblongo-lanceolatis, elliptico-lanceolatis vel oblongo-oblanceolatis, acutis vel acuminatis, marginis serratis; contractis in petiolum brevem, scabro-pubescentibus utrinque, 10-20 cm. longis, 2.5-3.5 cm. latis; medianis et superioribus foliis caulinis similiis praeter sensim decresentia; inflorescentia paniculata, dense pubescentia, bracteis rameis et ultimis ramis stipitato-glandulosis; capitulis nonsecundis vel obscure secundis; involucris 4.5-5 mm. altis; phyllis lanceolatis oblongatis vel oblongo-lanceolatis acutis, marginis et externis superficiibus pubescentibus et stipitato-glandulosis, valde costatis, 3 seriatis; ligulis 10-15; floribus disci 6-9; corollae lobis 1.3-1.7 mm. longis; antheribus 1.2-1.5 mm. longis; pappo 3.2-4 mm. longo; achaeniis 1.2-1.5 longis, pubescentibus.

STEM: erect; terete; glabrous or sparsely pubescent below, densely pubescent with upwardly curved hairs in upper half; green to straw-color; up to 1.5 m. high. BASAL LEAVES: absent at flowering time. LOWER CAULINE LEAVES: elongate-lanceolate, elliptic-lanceolate to elongate-oblanceolate; acute to acuminate; serrate; narrowed to very short petiole; scabro-pubescent on both surfaces; 10-20 cm. long, 2.5-3.5 cm. wide. MEDIAN AND UPPER CAULINE LEAVES: similar except gradually becoming smaller. INFLORESCENCE: paniculate; densely pubescent; *rameal bracts and ultimate subdivisions of axis stipitate-glandular.* HEADS: non-secund to obscurely secund. INVOLUCRE: 4.5-5.0 mm. high. PHYLLARIES: lanceolate, oblong, or oblong-lanceolate; acute; *margins and outer surfaces pubescent and stipitate glandular;* strongly costate; ca. 3 rows. RAYS: 10-15. DISC FLOWERS: 6-9. COROLLA LOBES: 1.3-1.7 mm. long. ANTHERS: 1.2-1.5 mm. long. PAPPUS: 3.2-4 mm. long. ACHENES: 1.2-1.5

mm. long, pubescent. CRESCENT, B. C. J. K. Henry, August and September, 1914. Type: California Academy of Science Herbarium No. 10089. Isotypes: Nos. 9988, 9989, 9991, 9993, 9994, 9995, 10088, 10090, 10091.

This form differs from the variety chiefly in the presence of stipitate glands on the rameal bracts, on the ultimate subdivisions of the axes of the inflorescence, and on the margins and outer surfaces of the phyllaries.

X SOLIDAGO *patuliginosa* sp. nov., caulibus erectis, cylindris, glaberibus praeter in inflorescentia, viridis vel rubris, 0.5-1.5 m. altis; foliis basilaris lanceolatis, acutis vel acuminatis, marginis serratis, scabris, contractis in petiolum longum marginatum, scaberrimis supra, glabris subtus, 2-3 dm. longis, 2-4 cm. latis; medianis et superioribus foliis caulinis similiis praeter sensim decresentia; inflorescentia virgata ad paniculata, scabro-pubescentia; capitulis nonsecundis ad valde secundis; involucris 3.8-4.5 mm. altis; phyllis ovatis, lanceolatis vel oblongatis, acutis vel obtusis, marginis ciliatis, ecostatis vel obscure costatis, 4-seriatis; ligulis 4-6; floribus disci 4-8; corollae lobis 1.1-1.5 mm. longis; antheribus 1.1-1.4 mm. longis; pappo 2.8-3.5 mm. longo; achaeniis 1.4-1.9 mm. longis, aliquantis nigris, glaberibus.

STEM: erect, terete; glabrous below inflorescence; green to reddish; 0.5-1.5 m. high. BASAL LEAVES: lanceolate; acute to acuminate; margins serrate, scabrous; narrowed to long margined petioles; very scabrous above, glabrous below; 12-25 cm. long, 1.5-3 cm. wide. LOWER CAULINE LEAVES: lanceolate, elliptical to ovate-lanceolate; acute to acuminate; finely to coarsely serrate; narrowed to margined petioles; very scabrous above, glabrous below; 2-3 dm. long, 2.4 cm. wide. MEDIAN AND UPPER CAULINE LEAVES: similar except gradually becoming smaller. INFLORESCENCE: virgate to spreading panicle; scabro-pubescent. HEADS: nonsecund to strongly secund. INVOLUCRE: 3.8-4.5 mm. high. PHYLLARIES: ovate, lanceolate to oblong; acute to obtuse; margins ciliate in upper half; ecostate to obscurely costate; 4 rows. RAYS: 4-6. DISC FLOWERS: 4-8. COROLLA lobes; 1.1-1.5 mm. long. ANTHERS: 1.1-1.4 mm. long. PAPPUS: 2.8-3.5 mm. long. ACHENES: 1.4-1.9 mm. long; blackish, glabrous 10-ribbed. Springy, peaty slope on Krieg farm, on north side of Salamonie River valley; 1 mile north and 1 mile east of Monument City, Huntington Co., Indiana. September 18, 1948. Type: Friesner No. 22501 in Butler University Herbarium. Also collected from similar habitat on south bank of Sugar Creek, 1 mile west of Darlington, Montgomery Co., Indiana.

In general aspect this hybrid resembles *S. uliginosa* var. *linoides* from which it differs in the taller stature, the very scabrous upper surface of the leaves, the larger number of rows of phyllaries, the ciliate margins of the phyllaries, and in the 10-ribbed achenes.

CHARA KIENERI, A NEW SPECIES FROM NEBRASKA

By FAY KENOYER DAILY

This species was named in honor of Dr. Walter Kiener of the Nebraska Game, Forestation, and Parks Commission who collected it and who has collected much other fine material from Nebraska.

Although the affinity of *Chara Kieneri* is most nearly with *C. excelsa* Allen emend. Robinson, it differs in several ways and is unlike any other Chara known to the author in that the anterior bracts and bracteoles range from the usual unforked condition, through a series showing some forms with a wide base suddenly narrowing, some with a slight projection, some forked with one short arm and one long arm, and finally some forked with almost equal arms.

Two other cases of forked cells in the Charophytes are known to the author. *Nitella partita* Nordst. (3) has been named from Australia. The tips of the ultimate rays were made up of bi- and tri-partite cells with cuspidate diverging points. Since the species was named from only one unripe specimen, Groves and Allen state, "It is most desirable that further specimens should if possible be collected to see whether the extraordinary lobed ultimate cells are normal." Another case of forked cells was described by Migula (2) in a specimen of *Lychnothamnus barbatus* (Meyen) Leonh. One bract was seen to be forked. Other unusual conditions were seen in this specimen and all were treated as abnormalities.

CHARA KIENERI SP. NOV.

Plate I

Habito ca. 30 cm. alto, laxo, elongato, gracili; monoica; caule ca. 0.75 mm. in diametro, irreguliter haplostiche- diplostiche- triplostiche-corticato, usualiter diplostiche- corticato; primariis cellulis prominentibus; spinulis variabilissimis, solitariis vel geminatis, brevissimis vel longissimis; corona stipulari variabilissima, serie supera ca. 0.225 mm., serie infera ca. 0.12 mm.; ramulis verticilli 7-8, infimis internodiis diplostiche-corticatis 2-6, brevibus ecorticatis apicatis cellulis 1 vel 2; bracteolis et anterioribus bracteis longis, gracilibus, acutis,

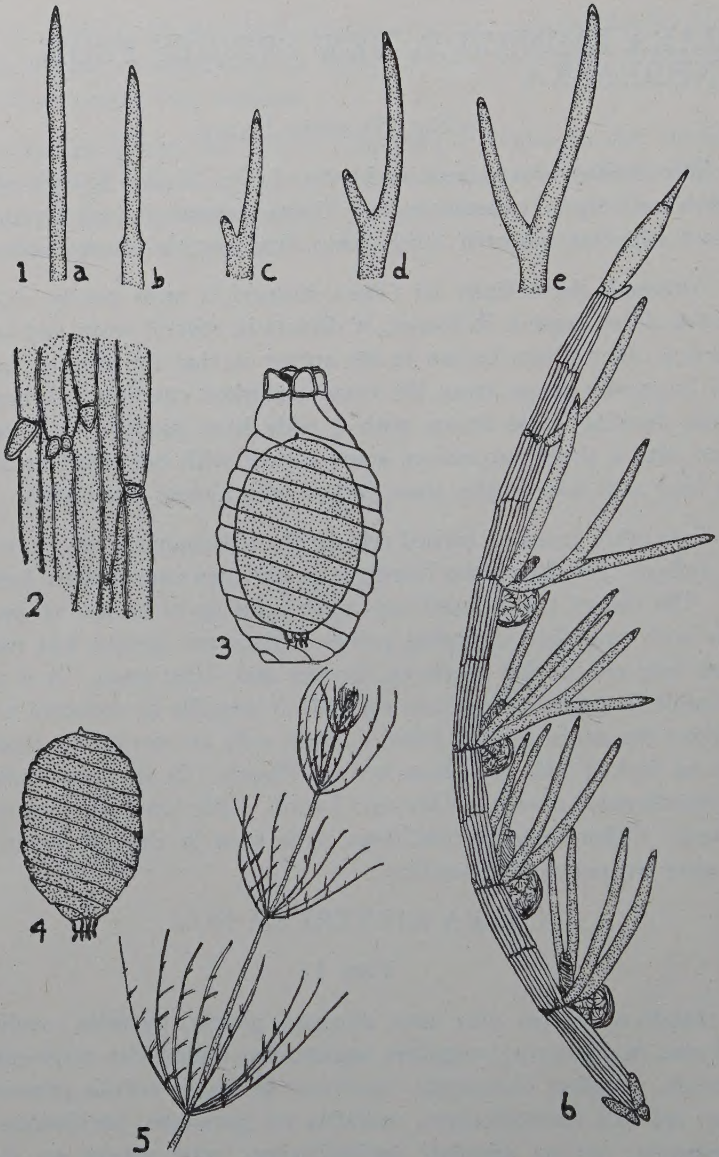

PLATE I. *Chara Kieneri* sp. nov. 1(a, b, c, d, and e). Showing different shapes of bracteoles and anterior bract cells. 2. Section of cortex. 3. Oogonium. 4. Oospore. 5. Portion of the plant. 6. Branchlet.

infurcatis vel furcatis; posterioribus bracteis brevissimis, infurcatis; coronula oogonii ca. 0.09 mm. alta; collo oogonii non elongato; nucleo oogonii brunneo, ca. 0.45-0.636 mm. longo, 0.375-0.525 mm. crasso, cum cavea, 10-14 gyrato non prominenter; exteriore colorata membrana nuclei brunnea, subtilissima granulato-punctata; antheridio 0.325-0.375 mm. in diametro.

HABIT: ca. 30 cm. high, lax, elongate, thin. MONOECIOUS. STEM: ca. 0.75 mm. in diameter; irregularly haplostichous, diplostichous, or triplostichous, usually diplostichous; primary cells prominent; no uncorticated internodes. SPINE CELLS: papillate to very long; usually single but sometimes geminate. STIPULODES: variable, usually 0.225 mm. long in upper series, 0.12 mm. long in lower series. BRANCHLETS: 7-8 at a node, 2-6 diplostichously corticated internodes, tipped by 2 short uncorticated cells. BRACTEOLES AND ANTERIOR BRACT CELLS: long, narrow, acute, unforked or forked. POSTERIOR BRACT CELLS: short, not forked. OOGONIA: with neck not greatly elongate, crown cells ca. 0.09 mm. high. OOSPORES: brown, ca. 0.45-0.636 mm. long, 0.375-0.525 mm. wide, with cage, showing 10-14 ridges not very prominent. Outer colored membrane: brown, finely granulate. ANTHERIDIA: 0.325-0.375 mm. in diameter.

Chara Kieneri resembles *C. excelsa* Allen emend. Robinson but differs in the following characteristics: Although it has spine cells produced singly and is essentially diplostichous with occasional triplostichous cortication like *C. excelsa,* it is also at times haplostichous and has spine cells produced in pairs; it does not have elongated neck cells on the oogonia; anterior bract cells and bracteoles are acute rather than acuminate and show great variation ranging from unforked through various degrees of forking; none of the internodes on the stem or branchlets are uncorticated; the oospore has a cage.

Type specimen:—Nebraska: Sheridan county: several plants in a large collection containing also *C. contraria* A. Br., *C. fragilis* Desv., and *C. excelsa* Allen emend. Robinson; east of Bingham, marsh pond, lat. ca. 42° N., alt. 3910 ft., *Kiener 20625,* May 23, 1946. (Type deposited in Butler University Herbarium, co-type to be found in the Walter Kiener collection.)

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